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STRATEGIC BOMBING AND THE THERMONUCLEAR BREAKTHROUGH: AN EXAMPL--ETC(U)

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(6) STRATEGIC BOMBING AND THE THERMONUCLEAR BREAKTHROUGH:
AN EXAMPLE OF DISCONNECTED DEFENSE PLANNING.

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ABSTRACT

Military missions should be based on the Nation's military objectives; in turn, force structure mix and size should be derived from the mission roster. One among many examples of a disconnection of the planning process that has led to trouble for U.S. defense planners has been in the case of strategic bombing. Because of the collapse of planning, and for technical reasons, U.S. strategic bombing in World War II did not achieve the objectives that air power enthusiasts had prophesied before the war. After 1945, some felt that the atomic bomb would solve some of the problems experienced in World War II. However, evidence suggests that atomic attack on the USSR probably would have been insufficient to knock the Soviet Union out of a major war. Unfortunately, nuclear air power came to be the core of the West's defense posture; because of the disconnection of the goals of bombing with traditional national military aims, the overall defense posture suffered. In turn, the development of very high yield Hydrogen bombs seemed to neutralize the technical shortcomings with fission weapons. Insofar as the thermonuclear breakthrough rationalized after the fact a segregated and isolated air power concept, the disconnections among forces, missions, and national goals became complete. Though reversed to some degree over time, the effects of severed planning brought about by adoption of a massive air power arsenal--endorsed by this technical development--continue to plague U.S. defense planning and foreign policy nearly three decades later.

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I. INTRODUCTION: DISCONNECTED DEFENSE PLANNING

In defense planning, the policy objectives specified in the Nation's strategy should give rise to a list of missions that our military forces must be able to carry out. In turn, taking into account threats and other considerations, we can straightforwardly develop an estimate of the numbers and types of weapons, personnel, and other resources that are needed to accomplish the total roster of required missions. When defense planning goes forward in this orderly way, we can be reasonably confident that our posture can satisfy requirements and defeat threats. But when this process fails, trouble follows.

There are many ways in which this idealized process can break down. Chief among these is the fact that we probably cannot afford to buy everything we would need to achieve all missions with high confidence. We then have to make tradeoffs among missions and we would need to accept more risk in preparing war plans and the force structure. Many factors influence the division of the "defense pie" among competitors for scarce resources. But there is no doubt that we stand the best chance of maintaining effective and efficient defenses if we try to keep doctrine, missions, and forces tied together properly.

Disconnection within the defense planning process in particular can lead to two serious problems. First, doctrinal rationales often prove incompatible with operational mission and force planning, usually because they are too vague or general to support detailed work. By contrast, other doctrine relating to force employment adequately supports narrowly focused plans for war fighting but fails to indicate

how accomplishing missions can enhance deterrence or grant combat leverage (and help to ensure an earlier or more favorable war outcome).

A second consequence of disconnected defense planning is that force structure and mission planning may occur independently. When appropriate overall doctrinal guidance is not provided to operational-level planners, decisions frequently will be made on the basis of short-range, "practical" considerations which may not be equally appropriate in both the force structure and employment planning arenas. Completely unlinked operational planning sometimes results. On other occasions, the most desirable pattern of planning (in which mission requirements form the basis for force structuring) is reversed. If missions are redefined in an arbitrary way, pressures applied to them by the force structure can even direct doctrine. The inertia of the inventory can profoundly influence operational plans and statements of war aims, though not necessarily to the national advantage.

Unfortunately, available evidence shows disconnected planning to be the rule, not the exception, in the U.S. experience since World War II. And nowhere are the consequences of disconnected planning more clear than in the strategic nuclear forces. In the United States, nuclear planning since World War II typically has been confused and ineffective because we have no verified theory that describes how strategic air power can be used to, say, force the enemy to stop fighting. And because doctrinal guidance has not been available to planners, forces and war plans have tended to evolve for reasons having little to do with national goals. As a result, U.S. strategic preparations may not be well suited to policy. In any area of defense planning this can be a

serious problem: it is all the more critical in the strategic forces given the destructive potential of nuclear weapons, and their pivotal role as a deterrent to a broad range of threats.

Now our strategic planning problems will not evaporate magically if, somehow, we can restore the planning linkage. Sometimes there are no good answers at all, and political and other factors act to shape nearly all defense decisions. In the final review, though, U.S. nuclear planning suffers inordinately because we fail to tie nuclear doctrine to war plans and, thence, to the posture. (And indeed, defense managers have recognized relinking of force structure and employment planning fracture to be a prerequisite to restoration of sound nuclear policy planning. The integration of forces and war plans has been assigned high priority in the Secretary of Defense's Annual Reports since January 1978. Further, one of the purposes of the so-called Presidential Decision Number 59 was said to be to prevent designated U.S. war goals from outrunning the true capabilities of the posture.)

Identification of the causes of planning disconnections is an essential prelude to remedying planning failures. But while the consequences of disconnected planning are obvious, the properties of defense planning disconnects are generally obscure. To effect a reconnection requires a better understanding of the relationship of doctrine to force and employment planning than is now in hand.

To illuminate some important aspects of this relationship, I here describe the interaction of doctrine, plans, and technology in the case of the U.S. decision to develop the hydrogen bomb. The United States decision to proceed with the development of thermonuclear weapons has

been widely debated and discussed. The hydrogen bomb experience contains many frills: atomic espionage, interservice rivalry, the role of technical advisers, differences of opinions over scientific and engineering issues. But to the student of defense planning, the most noteworthy effect of the hydrogen bomb was to provide an apparent technical solution for an important, but foundering, military mission.

In turn, the development of the H-bomb seemed to render effective the air power doctrine that had nearly been dealt a death blow, first by poor performance in World War II, and then by U.S. inability to solve the major technical deficiencies that plagued postwar atomic forces. The thermonuclear example, then, is a classic one in which the planning process collapsed while major policy reorientations were nonetheless accepted solely on account of the bomb's enormous explosive power. In this paper, I will first discuss the doctrine of strategic bombing and its influence on early U.S. nuclear war and force planning. Then I will show that the failure to develop a strategic bombing doctrine caused war planning to become, first separated from, and then driven by, the nuclear force structure.

In brief, I will develop the following points. Unhappy combat experience to the contrary, various schools of thought have since 1917 invested strategic air power with the independent ability to deter war, based on air power's putative ability to win wars "single handedly." Despite dramatic changes in weaponry, technology, and tactics, this view has not changed. Some proponents of bombing have consequently tried to assign to air power a pivotal role in overall national military planning. When they have succeeded, air power doctrine has indirectly

driven diplomatic and other developments and influenced overall defense budget allocations.

But because classic air power theory is disconnected from other aspects of military planning, adoption of strategic bombing as the Nation's first line of defense can be part of the cause of a disconnected general national defense strategy. In fact, after 1950, U.S. devotion to nuclear air power led to disintegration of the defense effort. And, although we have broken away from a nearly singular reliance on strategic air power since 1960, serious gaps remain. These gaps are the almost inevitable result of the evolution of strategic air doctrine over four decades.

Wartime experience in both major theaters of operation in World War II did not endorse completely the prewar claims of strategic air power enthusiasts. Bombing accomplished relatively little and cost a great deal. As soon as atomic bombs had been used against Japan, however, it began to be suggested that atomic firepower would neutralize the problems that acted in the War to undermine the effectiveness of conventional bombing. In this way, the demonstration of the atom bomb seemed to keep alive contention that air attack could be decisive in any future war, at costs much below those needed to maintain large standing armies and navies. Because of tightening defense budgets after Fiscal Year 1946, this debate enjoyed more than academic significance.

As we shall see <u>infra</u>, serious technical problems remained with atomic bombing. It was not clear through 1952 that fission weapons could then or in the forseeable future surmount severe aiming, intelligence, survivability, and other hurdles and deliver an advertised

knock-out blow against the Soviet Union. Before 1953, the inability of the USAF to remedy some of these operational deficiencies, the explosion by the USSR of its own nuclear weapons, and the decision by the United Nations to fight a conventional war in Korea reignited official consideration of whether major reliance on an atomic striking force was a prudent policy.

Materializing at this crucial juncture, the demonstrated power of the hydrogen bomb seemed to dissipate in one decisive stroke the arguments and doubts of those critics who alleged that strategic bombing could not destroy in short order the war-making potential of an enemy nation. Needless to say, this "miracle" military development influenced heavily the development of U.S. military policies and the posture throughout the rest of the 1950s. In particular, in January 1954, Secretary of State Dulles announced the "Massive Retaliation" policy, a doctrine which, founded on the new capability represented by thermonuclear weapons, formed a primary theme for all U.S. foreign policy and defense planning through 1961. Moreover, as U.S. security policy came to be addicted to nuclear weapons, budgetary shifts over the decade came to favor the strategic retaliatory forces, with ominous implications for other combat arms.

In retrospect it is clear that the H-bomb's mission of wholesale "city busting" was ephemeral. Large-yield thermonuclear devices for the most part were phased out of the U.S. arsenal beginning in the early 1960s. Today the chief perceived advantages of the thermonuclear breakthrough has been its application in light-weight ballistic missile warheads and in tactical and tailored effect weapon systems--not in

weapon systems and employment concepts designed to obliterate in short order the economic and social structure of the USSR. Unfortunately, the residual effects of the U.S.'s adoption, in the 1950s, of a massive deterrent strategy based on high yield H-weapons continue to shape the posture today. The results, seen most strikingly in NATO's reluctance to commit resources to the conventional defense of Europe (but in other cases as well) are generally considered to be adverse.

The case of the hydrogen bomb therefore is one in which force structure developments came to dominate war planning leading, in turn, to a revision of U.S. strategy objectives in general nuclear war. In retrospect, we may be worse off in the long run because the United States' commitment to indiscriminate urban/industrial attack locked the nation into a set of employment concepts that have excessively shaped posture and policy since that time. The inference that can be drawn from this case-in-point is that the posture and plans should then have been placed more tightly under the control of planning of the nation's overall war aims. Because such higher level deliberations remained disjoint from rapidly changing operational conditions, however, we were forced to contend with strategic planning problems which owed much of their virulence to the early disconnection of policy and operational planning.

II. THE DOCTRINAL PREDICATES OF AIR POWER

From a military perspective, the most striking consequence of the invention of the hydrogen bomb was the complete liquidation of any continued doubt that nuclear weapons could not be "decisive" in future conflict, in the sense of fulfilling the classical theoretic aims of a strategic bombing campaign. Even those determined skeptics who had doubted the military significance of purely fission weapons admitted readily that the hydrogen bomb did make possible air campaigns based on the one-shot, war-winning, annihilation attacks on which most schools of air power had been based since the 1930s. Summing up this development with his usual eloquence, Churchill pointed out in 1955 that there was "an immense gulf between the atomic and the hydrogen bomb. The atomic bomb, with all its terror, did not carry us outside the scope of human control or manageable events in thought or action, in peace or war."[1]

Today, people tend to conceive of nuclear weapons as a continuum of explosive devices ranging from low-yield tactical weapons on up to "purely" strategic explosives. This is partly a bias dating from shifts in the yields of the U.S. stockpile beginning in about 1960. It is easy to forget that in the early 1950s most weapons had about the same power, and that no differentiation in type or function was attributed to higher yields *per se*. Guiding principles, such as "bigger is better" or "more bang for the buck," did not reflect deliberate decisions to military ends, but rather bespoke technical problems with nuclear weapons of all types. In this context, the development of a range of forces including substantially more powerful weapons could not help but change the

principles of employment planning.

That being the case, what were the specific consequences for planning of the hydrogen bomb's thousand-fold increase in explosive power? As with any military capability, we should rationalize our proposed wartime employment of nuclear weapons and our peacetime investments in the strategic force structure in terms of some theory of how these forces (together with our nuclear war employment plans) would contribute to deterrence or to relatively acceptable war outcomes if deterrence fails. But force and employment planning for air power have been disconnected (and have therefore not best operated in the national interest) mainly because no one has devised any good theories on how air power can contribute to traditional national wartime aims. We can attempt to figure the advantage of say, an extra division of ground forces, in capturing, punishing, or repelling an enemy. We can also look, in the same context, at how well tactical air and naval forces can support a land campaign. But, overall air policy planning has never convincingly explained the means by which every addition to the posture or offensive plans can trade off with the likely success of a general campaign.

This deficiency mainly is a consequence of our tendency to rely on abstract and isolated air power doctrines. Because air power cannot by itself accomplish traditional military objectives (such as the occupation of enemy territory) these theories have for decades concentrated instead on the ability of strategic attack to accomplish autonomous objectives (for instance, destruction of the "enemy's will to continue fighting"). Because air power can only destroy (and not

control or seize), two central questions for planners are: what targets should come under attack to produce desired results, and how fast would the results of attack materialize?

In the 1930s, a major difference of opinion emerged on these two points of strategy. For reasons having little to do with combat issues, some advocates accepted the theory popularized by the Italian General Douhet and others that the crucial air target should be the popular support on which a hostile regime relied. If bombing could dash enemy morale, so it was argued, subsequent public reaction or apathy might compel hostile leadership to desist shortly from continued conflict. As that doctrine was embraced by some European air services and a few theorists in the United States, destruction of undifferentiated housing and industrial plant became an all-purpose air campaign objective.[2]

Other theorists, including many planners in the RAF Bomber Command and the U.S. Army Air Force, devised a targeting policy aimed at specific vulnerabilities in an enemy state's economy.[3] They thought that the best war plan would attack key targets in depth sufficient to destroy vital inputs to other industrial enterprises. As self-reinforcing shortages strangled the enemy's war-sustaining potential, the enemy's means for continuing the fight should grind to a halt. This strategy came to be known as "bottlenecking," because the bomber offensive would be aimed at bottlenecks or chokepoints in a foe's economy.[4]

To be sure, even among precision air attack advocates, in the late 1930s, the terror bombing sword was rattled and declaratory emphasis was placed on annihilation attacks for the sake of deterrence. But

disastrous combat experience in 1939-40 promptly dislodged British proponents of the precise attack school. Although the Royal Air Force first unleashed a daylight precision offensive against the Continent, 1940-vintage RAF medium bombers were too lightly armed and had insufficient ceiling to repel or avoid Luftwaffe day fighters and flak, and per sorties attrition rates quickly came to exceed reasonable limits.[5] Due especially to shoddy navigation but also to fierce defenses and the lack of proper bomb laying gear, moreover, British bombing was wildly inaccurate. Systems analysts compared the costs and payoffs of the early bombing campaign and recommended the immediate termination of the air offensive.[6] Churchill rejected this finding on several grounds. Not only was the continuation of the air offensive the only feasible aggressive action which could be taken against Germany, but Churchill saw a need to retaliate for German bombing of British cities. Further, at the time this debate took place, three new four-engine heavy bombers, representing a lion's share of British pre-war rearmament program, began to come on line.

The British compromise among all of these factors was to convert, after Summer 1941, to nighttime area bombing. Luftwaffe defenses could not yet intercept on radar close control, and RAF losses initially were negligible. Often, city centers were used as aiming points.[7] Ultimately, new hyperbolic navigation techniques, specially trained pathfinder crews, and a high mix of incendiary to high explosive bombs rendered night bombing a highly destructive if not terribly effective option.[8] Area bombing not only proved a practical resolution of troublesome penetration and accuracy problems, the strategy was

consistent with the views of Air Marshalls Slessor, Harris, and Tedder who expected such attacks to have a consuming morale effect. "During World War II, confidence in the famous British stiff upper lip produced a conviction in some military and political circles in Britain that German morale would not equal that of the British under terror bombing, and that such bombing might well lead to a German revolt."[9]

Of doctrinal note, the area bombing philosophy was supported by a body of economic theory endorsed by Bomber Command. In 1942, Ambrose Congreve, a civilian attached to the Air Ministry, suggested that the best air objective would be large and indistinct, but highly capitalized industrial complexes. The Congreve strategy more or less assumed that the cost to the enemy of replacing capital should be the major criterion for preparing attacks.

U.S. European Theater strategic air forces, for their part, persisted in daylight operation, despite pressure, especially from Marshall Harris, to join in night raids.[10] The United States' 8th and 15th Air Force strategic targeting effort was headed up by the "Enemy Objectives Unit", a combined staff consisting of representatives from OSS, the Bureau of Economic Warfare, and USAAF, charged not only with fragging sorties, but also with assessing the consequences of air attack. EOU analysts suggested that destruction of 40-50% of capacity in some key industries would accomplish the bottlenecking objective, a contention rejected by the area bombing theorists.[11] The EOU strategy differed further with the Congreve strategy in assumptions made about the costs and payoffs of bombing, the psychological and administrative effects of air attacks, the delay in onset of effects of attack, and the

duration of disruption caused by bombing.

The outcomes of both bomber offensives have been studied extensively, and impressions of the validity of the two theories came to figure in post-war debate on how U.S. atomic air forces should be targeted and on the effects that atomic bombing might produce. Predictably, as neither strategy had performed anywhere near projected standards, the cases "in favor" of either strategy seemed to rest most heavily on the faults of the other.

For its part, the American European campaign failed on account of high attrition. By the summer of 1943, per sortie attrition to German targets was tending towards double digits for aircraft not returning, and counting returning crew casualties and recovering but irreparable aircraft, losses often exceeded one-fourth of planes and men entering the air battle. By comparison, most airmen consider three or four percent attrition catastrophic for sustained operations for, at only 3% average attrition, the odds of surviving a 25 mission tour are worse than 50:50. And at 15% attrition, an aircraft will survive, on the average, less than four sorties. Thus, the catastrophic results of the second mission against Schweinfurt on 14 October 1943 (which amounted to about 21 not returning and more than 68% not returning or recovering with severe or irreparable damage) signalled the decisive defeat of the U.S. strategic bombing campaign pending the introduction of long-range escorts and the attainment of general air superiority later in the war.

The British aerial bombing campaign was able to operate at acceptable attrition until the Spring of 1944 when German radar and night fighter capabilities could at last pose similar risks to Bomber

Command. The British "Schweinfurt" came during a 30 March 1944 attack against Nuremburg that saw the loss of 94 of about 800 aircraft (with serious damage to 72 others). However, while the British did not until this relatively late date sustain casualties on a par with those of the USAAF, they had apparently accomplished to that date almost nothing of practical military consequence. There is even evidence that indiscriminate British fire attacks precipitated a reverse morale effect.[12]

In short, much evidence indicates that neither the RAF and USAAF campaigns accomplished any very tangible military aim, most notably an earlier end to fighting. Society had hung together and production had not been seriously undercut in Germany until late in 1944; when the fabric of the German economy began to deteriorate in early 1945, it was due to many factors. At the same time, the costs of the offensive were high: U.S. and British losses combined ran to about 10,000 bombers shot down and more than 150,000 airmen killed.

But in August 1945 the atom bomb was dropped on two Japanese cities. Although the damage done by these attacks was not remarkable compared to that inflicted in the previous 12 months by devastating B-29 fire raids carried out by General Curtis LeMay's 20th Air Force, great inspiration was given to new argument on the question of whether the atom bomb's destructive power could overturn the many demonstrated obstacles to successful prosecution of either of the leading air strategies. Specifically, some argued that atomic bombing could satisfy the requirements of the various World War II air schemes, and knock future foes out of the war by air attack alone. The question of which

air strategy was to be adopted predictably became a key point in the defense debate of the late 1940s.

On the one hand, as the bomb represented a thousand-fold improvement in destructive power, it seemed ideal for Congreve attacks, which stressed destruction of plant. Arguing further in favor of the adoption of annihilation bombing was the fact that poor economic intelligence and analysis--characteristic of the USAAF's European experience and certain to continue to apply given Soviet secretiveness--would support area, as opposed to precision, attacks. Even if it yielded only in the 10-20 KT range, the A-bomb could destroy several targets of interest in a metropolitan area. The atom bomb also produced substantially higher numbers of fatalities for equivalent economic damage done by high explosive weapons. For example, in raids on Hamburg, Frankfurt, and Kobe, 48%, more than 33%, and more than 50% of all housing was destroyed respectively, but fatality rates were low.[13] Per acre of urban area destroyed to similar degrees, the atom bombs on Hiroshima and Nagasaki proved three to four times more deadly. This was due in part to surprise and in part to the bomb's nuclear and thermal radiation output and to its greater ability to knock down structures (thereby producing most casualties) by a relatively long dynamic blast phase.

On the other hand, most U.S. theoreticians felt that, even with the atomic bomb, an area attack strategy should not be adopted. For one thing, that approach necessarily assumed capital to be unspecialized, and increased bomb yields alone would not resolve the question of which types of output were most important. Furthermore, area attack schemes

would not reveal target system peculiarities, and so the opportunity would be lost, under that theory, to gain any "miracle target" advantages through judicious aimpoint selection. But from the U.S. planner's perspective, the most serious liability of the Congreve approach was that its payoffs were delayed, mainly because it did not take into account such factors as goods-in-transit, substitution possibilities, stockpiles, self-replicating and reinforcing capabilities of targets, and so on. A supposed advantage of a precision bombing strategy was prompt destruction of the enemy war effort. By contrast, an area campaign was thought to be more like a naval blockade which exerts a slow, but certain, stranglehold on the enemy.[14]

The timing of effects would not be terribly relevant if the U.S. were to be obliged to reinvade Europe in a replay of World War II. But if the goal was to prevent the USSR from overrunning the continent in the first place, then it is crucial that the effects of bombing materialize quickly. The alternative to quick results, of course, would be the maintenance of a large U.S. Army in Europe to check the Soviets while the effects of bombing slowly matured. Selecting a policy of demobilization (and given the Soviet failure to reduce their much greater land forces), the need for a fast bombing payoff was very apparent. Hence this theoretic distinction between the area and precision approaches came, for reason apart from doctrinal predilections, to be linked with overall postwar force structure choices.

While severe intellectual and operational difficulties remained with each theory it seemed to be the case that if enough weapons were

available, an atomic campaign could be conducted simultaneously against many installations in a vertical target array, enhancing the effectiveness of a precision attack. (With conventional bombs, the delays resulting from a requirement to mount one by one attacks on all relevant targets had permitted the enemy to jury rig surviving capability and compensate for at least part of the damage done by the attack.) The atom bomb also promised a higher probability of kill against some hard targets, and destruction--by both blast and fire--would be widespread, destroying rescue, repair, and substitution capabilities as well as the intended target. Mutually supporting capabilities would be destroyed simultaneously, complicating recovery.

On the other hand, atomic weapons also would unavoidably produce considerable collateral damage to workers' houses. Given that 50% of the population exposed to 5 psi would die, approximately 19% of Soviet population would be killed by 20 KT weapons delivered against a full range of Soviet industrial installations.[15] (Indeed in 1948, an official technical panel designated as an appropriate atomic target "a vital war plant employing a large number of workers and closely surrounded by workers' houses."[16]) This did not mean that the U.S. would seek to kill people as a specified objective of air attack; rather, the destruction of housing and labor would "administer maximum surprise and shock." And it so happened that "the mass killing of noncombatants came to be viewed as a bonus effect, a useful by-product of the bombing campaign on which we relied to win the event of World War III. Our knock-out blow would paralyze the Red Army not only by demolishing railroad yards, factories and party headquarters but also by

decimating urban population and thus (perhaps) crushing Russia's morale."[17] In this way, the atom bomb at once strengthened the cases of both by virtue of the simple fact that atomic attacks apparently could destroy precision targets while doing area damage as well.

So was the line developed that A-bombing could compensate for certain problems experienced in World War II. This debate smacked of hindsight; and physical scientists, economists, and social scientists were involved in esoteric discussions as never before. Yet, if the issue seems academic today, the debate was quite real in the immediate postwar years. The choice of one strategy or other would have major implications for the U.S. force structure in aggregate. Indeed, almost immediately after its creation as a separate service in 1947, the U.S. Air Force engaged in a bitter confrontation with the Navy over which service should assume the role of America's first line of defense. The Navy, until it had developed a plan for carrier based atomic air power, argued that the need to control the Mediterranean, key oil routes, and other oceanic lines of communication were paramount objectives. The Air Force averred that atomic bombing would prove the most devastating reply to the USSR should it threaten U.S. interests (and before land and sea offensive capabilities to hold or reinvade, say, Europe, could be mustered). Insofar as combat missions and budget representations were at stake, the debate evolved into a major crisis just prior to the Korean War following cancellation of the Navy's proposed supercarrier, the USS United States, in favor of an air force posture along the lines of that recommended by the pro-bomber Finletter commission. Although the United States was shortly to intervene on the ground in Korea, the

Air Force managed to promote air power as a substitute for expensive conventional forces just as the RAF had so convinced Parliament before World War II. In point of fact, the misery of the Korean ground conflict helped to convince the home audience that overwhelming strategic air power was, more than ever, urgently needed.

In short, the point was settled in favor of the Air Force's doctrinal claims because bombing could deter Soviet aggression and could also provide the cheapest defense if worse came to worst. But with the ascendancy of the atomic deterrent, the posture began to drift into segregated capabilities, as had been the case with the air war in World War II. Just as in the Second World War, it is interesting to recall, the "air battle" came to be the focus of segregated planning. In World War II, U.S. Strategic Air Forces Europe were not only doing relatively little, prior to late 1944, to cut German industrial and military output, the nature of the objectives selected for attack had come to be segregated from the mainstream of the war as well. Because all air theories stress early acquisition of air superiority in order to permit the subsequent economical targeting of the widest range of enemy industries, the first goal of an air campaign is to gain control of the air mainly by destroying the enemy's ability to deploy and operate its own air forces. Hence, principal combat objectives of the 8th Air Force became German fighter production facilities; crucial accessory installations to air operations (most notoriously ball bearings); and petroleum. In a tail-chasing spiral, U.S. bombers sought to neutralize German fighters whose job in turn it was to intercept the bombers.[18] Accordingly, the core of U.S. air potential became separated from

overarching contingencies and military problems that the U.S. might face, except for those occasions when bombers were ordered to support land objectives, like TORCH and OVERLORD, that is the allied invasions of North Africa and Normandy.

Nonetheless, this and other lessons were overlooked even as the defense sceptre was being handed over to strategic bombing forces in the early 1950s. Ardent bombing supporters contended that air operations in World War II could have "won the war single handed" if only the bomber offensive had been sustained long enough to bring down the enemy's productive capacity or her adversary population's support for the war. As noted, this theory requires that the air war be isolated from the rest of the struggle, for the battle for air supremacy can then be justified at any cost. From the perspective of overall planning, bombing can be a valued supporting capability. But once air attack becomes the pivot of the total defense, trouble can arise.

In sum, if we plan strategic forces only on the basis of the leading air bombardment theories, we disconnect force and employment planning; the payoffs of our bombing operations are cast in an abstract light that is not subject to criticisms that might be apparent in the light of traditional war aims. The most important implication of this point is that the air war comes to be considered an enterprise apart from the main objectives of the war. The corollary of this finding is that unless bombing is directly applied to other war activities, it tends to accomplish little.

III. OPERATIONAL PROBLEMS CONTINUE DESPITE THE ATOMIC BOMB

Strategic nuclear planning after 1945 was shaped by concepts of independent vertical bombing tested in World War II. After the war, the official U.S. Air Force view of the military potential of strategic air attack continued to ascribe faithfully to part of that tradition. Although there are difficulties in translating World War II conditions to today, review of the historical foundations of strategic target selection provides insight into contemporary planning difficulties. In the cases both of the U.S. and U.K's preparations for World War II, and American planning for nuclear war since then, the missing part of the planning equation has been how military employment of strategic air could contribute to larger goals. Now, just as in the 1930s, when forced to argue the case for bombing in cost-effectiveness terms (usually in support of upcoming acquisition decisions) proponents cite every "advantage" of air power save this most important. The forgotten bottom line is that we have to justify our strategic program by its contribution to the goal of ending war on favorable terms, and not by its potential success in what could be--if war aims including termination were not considered--an irrelevant exercise.

After World War II, most strategists in the U.S. felt that the precision approach to bombing had been vindicated by review of war outcomes. Contrary experience, such as that of the 20th Air Force's area attacks on Japan in 1945 and the 8th Air Force's shift in Europe during the last few months of the war to area bombing (by using all-weather radar to look through prevailing European cloud cover), was

ignored. As noted, the precision bombing theory was sustained in the United States because it was believed that such bombing could produce decisive results quickly. If a future war could be won promptly by nuclear air forces, the rationale for the maintenance of large standing conventional forces and their support infrastructure (required if a long conventional war of attrition was expected to follow a nuclear exchange) would be undercut. If a Congreve-like scheme were adopted, on the other hand, there could be a proportionately larger requirement for general purpose forces. At the least, this force would have to be able to at least hold an enemy's onslaught until the U.S. could mobilize its superior industrial base.

As noted above, resolution of this theoretical debate therefore could influence not only the future character of the U.S. strategic air arsenal but the military posture as a whole. Yet, although precision air power was accepted as a cornerstone of defense, employment planning was carried out on an <u>ad hoc</u> basis and no one tried to answer the question "how much was enough?" To be sure, American planners were cognizant of a possible long-term Soviet threat. Even so, military capability did not seem to be a dominating factor in the U.S.'s foreign policy. For example, the United States deliberately elected, when tightening budgets made this particular choice necessary, to trim its defense budget as opposed to undercutting the Marshall Plan.

One symptom of the prevailing U.S. attitude was that postwar strategy did not specify in operationally useful terms how the Soviet Union should be defeated in the event of war. A defense concept vaguely cast in the image of World War II came to fill the void. United States

air power would strike an early nuclear blow, following up with conventional ordnance when the atomic arsenal was exhausted, establishing the perimeter behind which the nation could mobilize to flesh out a cadre army (promptly it was hoped) by virtue of Universal Military Training.

Specific requirements for air power within the context of this defense strategy equally were not clear. In fact, and despite their important and growing role in the defense posture, strategic force planning was conducted in a casual and short-ranged fashion through 1950. In turn, U.S. war plans simply applied available weapons to an ever-expanding Soviet target base in a routine fashion. Tight budget constraints and the lack of any basis for overall national defense planning especially account for the failure to devise force and employment policy early on for the U.S. strategic nuclear forces.

But nothing was done to resolve such points. In 1948, for example, the NSC-30 study attempted to address the important question of the circumstances under which the President might order the use of nuclear weapons. No agreement was reached, however, and the issue was left deliberately vague. As a result, atomic weapons were barred from the body of the JCS Emergency War Plan through 1949.[19] For the same reasons, force structure and sizing policies evolved at a glacial rate. Through 1947, "the military was slow to establish goals for nuclear production because early target lists and intelligence estimates were tentative and the military role of the atomic bomb was not yet clear."[20]

Eventually, a Joint Strategic Survey Committee was asked to estimate the nuclear force needed to destroy the USSR. In October 1947, the JSSC advised the AEC through the Joint Chiefs that "a military requirement exists for approximately 400 atomic bombs of destructive power equivalent to the Nagasaki type bomb," at least over the short run.[21] Two years later, and taking into account the requirements of expanded targeting, the "Harmon Committee" report led to new stockpile goals which saw an increase of the JSSC's force objective to a new level of approximately 1000 weapons.[22]

Despite the failure to prepare a coherent atomic air policy by about 1950, more and more people agreed that atomic air power would play an important role in the overall U.S. deterrent posture. But because of the lack of overall guidance, one principal effect of this new perspective would be the weaning of the air and atomic offensive from traditional campaign planning. For three main reasons, debate on the potential of atomic power came to mirror discussions on the autonomous capabilities of high explosive bombing that had taken place in the late 1930s.

First, some initially optimistic estimates of Soviet postwar intentions were discredited beginning in 1947. Capping a string of Soviet instigated regional crises came the disturbing demonstration by the USSR in 1949 of an atomic capability and a means for delivering it, the Tu-4 bomber. Second, American disgust with the Korean experience incited interest in enhancing the reliability of the deterrent. It was pointed out that, while the probability of aggressive action against the United States and its allies might be low, "reasonable" deterrents had,

at Pearl Harbor and again in Korea, been proved ineffective. The best way to shore up deterrence, many felt, was to use the new U.S. atomic capability to threaten would-be aggressors with massive and instant damage. The third precipitating factor was the failure of the Western allies to assume the burdens to maintain the capability needed to deter and win a new war fought by conventional arms. True, the United States had by early 1950 undertaken or promoted such defense improvements as: support for German rearmament; the NSC-68 plan; the Lisbon plan for 96 European and American divisions by 1954; a series of mutual defense treaties and agreements (including NATO itself); and the Truman Doctrine of containment. In practical terms however, the West then lacked the military might needed for credible conventional defense.

In short, before 1950, the United States had conceived a broadly based (if insubstantial) strategy only a single component of which was atomic air power. The essential shift of the following few years, of course, was the fulminating importance of atomic bombing in Western strategy relative to conventional preparations. Because U.S. planners were inclined towards precision targeting, the doctrinal predicates of atomic bombing were established on the basis of refined and careful application of available weapons to targets. Throughout this period the U.S. persevered in a policy of precision bombing for three reasons. First, the strategy was budgetarily attractive. Second, bombing was seen as part of a larger U.S. deterrent. Third, the strategy continued from World War II on the basis of sheer doctrinal momentum.

A crucial corollary to this strategy was that strategic bombing had to produce prompt results. The quicker the effects desired, however,

the more demanding we must be on our models, intelligence, operational performance, and so on. A very important factor in this regard is that despite adoption of this theory, operational constraints of the early atomic forces prevented the fulfillment of the proposed U.S. bombing strategy. As these deficiencies influenced operational planning, the danger then emerged that U.S. doctrine would be isolated from capabilities. Accordingly, while the effectiveness of strategic nuclear bombardment was an essential question before policymakers in the late 1940s, the technical nature of the bombing problem had little impact on force requirements and employment rationales. Rather, due to severe technical and operational inadequacies, estimation of the outcomes of bombing were made for reasons independent of military considerations. Indeed, little in the way of diagnostic analysis was conducted to identify areas for remedy.

For one thing, before 1950 it was difficult to predict bomb effects with any certainty. The weapons exploded over Hiroshima and Nagasaki literally were cumbersome laboratory devices. The Hiroshima bomb had yielded, at best, at perhaps about 60% of its design power. LITTLE BOY, dropped under perfect conditions, missed its nominal aimpoint by a considerable distance; likewise, FAT MAN's designated target sustained only moderate damage.[23] Both weapons were toggled at the wrong altitudes, ruining accuracy and undercutting target coverage.[24] These first-generation bombs required a highly trained team to prepare them for action and weighed so much (10,000 pounds for the Nagasaki-class Mk-3 bomb) that only specially modified B-29s could carry the weapons:[25]

> An atomic bomb approached a small airplane in size...Inside its ballistics case, it carried an incredible array of precision instruments, electronic gear, exquisitely machined and plated mechanical parts, expertly cast shapes of high explosives, and a core of fissionable material resembling the most ingenious Chinese puzzle. Production and assembly of weapons...would have been a challenge even if there had been well-established (production line) techniques.[26]

Lack of experimental data frustrated improvement of the weapons, yet remedial testing was countermanded by a fissionable materials shortage. A three-shot test, CROSSROADS, was ordered for the summer of 1946, but unfortunately the two tests actually held led to few practical improvements. Data collection was poor, due to inadequate instrumentation,[27] and the limited test results acquired were discouraging. Device ABLE, dropped under optimum conditions against an array of captured and obsolete naval vessels at Bikini, fell thousands of feet west of its brilliantly painted target, the USS NEVADA.[28] After this 30 June 1946 explosion, scientists hurried to the scene where they were astonished to discover test goats aboard target vessels alive and well.

Needless to say, such results were exploited by those who opposed exclusive reliance on atomic air forces. The "seemingly inexplicable error (of ABLE) opened the way for the Navy to question the Army Air Forces' bombing accuracy and the feasibility of employing the atomic bomb in this manner."[29] Against precision targets, aiming accuracy would be crucial for weapons with yields on the order of a dozen or two kilotons. If we are aiming at representative industrial targets, a CEP of 4000 feet and yield of 20 KT combine--if the weapon is ideally fuzed--to produce a probability of kill of only about one in six.

Unhappily, then, in 1950 a technical appreciation of U.S. bombing accuracy noted that 1000 feet CEPs had been obtained "using optimum per point radar targets, [but that] errors averaging 4,000 feet or more must be expected against industrial concentrations" under more likely operating circumstances.[30] Another official document noted that a 1500 foot CEP planning factor which the Air Force had been using in its effectiveness calculations "would serve only to mislead," and that at least a 3000 foot factor, probably more, should be used instead.[31]

Another technical problem exploited by opponents of full reliance on a ready strategic bombing force was widespread ignorance of bomb effects. There is, for example, the testimony of Commander Tatum, who advised a Congressional panel that they could stand at one end of the runway at National Airport with "no more protection than the clothes you now have on, and have an atom bomb explode at the other end of the runway without serious injury to you."[32] In this vein P.M.S. Blackett compared Air Force projections of atomic bomb damage to the gross exaggeration of the destructive potential of high explosive bombs before World War II. Using the analogy of the RAF overestimation of the effects of conventional air attack ("one of the greatest numerical blunders of military history"), Blackett contended that "a determined folk will learn to stand atomic bombardment, if that is their fate, just as the Germans learnt to stand ordinary bombing on a scale up to fifty times larger than that which the enthusiasts for strategic bombing thought would bring about the collapse of their war effort."[33]

Doubts about the destructive potential of the nuclear deterrent force were further fueled by serious shortages. USAF staff reviews of

1946-48 acknowledged the gross inadequacy of the atomic deterrent, owing mainly to personnel and equipment shortfalls.[34] At the time, the U.S. relied on expensive and vulnerable imports of Uranium from the Belgian Congo. Production reactors at Hanford had degraded on account of heavy use and deferred maintenance, threatening Plutonium availability. Because only two bomb assembly squads had been constituted by 1947 the U.S. could then activate, in an emergency, only a pair of weapons a day. (This was to be improved the next year, when a third assembly team was scheduled to be formed up; seven teams were projected to be active by July 1949.[35])

Further, only 27 B-29s had been atomic-modified by January 1946, all at the 509th Composite Group, Roswell Field NM; one report notes that only 5 more bombers had been added two years later. Another source notes that the atomic capable Air Force consisted of only 33 specially modified aircraft by January 1948. And it is said that by late June 1948, "fewer than 40 B-29 bombers were able to carry the unwieldy nuclear weapons; the atomic stockpile contained only a slightly larger number of bombs, many of which were later discovered to be unusable; and there were neither bombs nor delivery aircraft located outside the United States and within range of the Soviet Union."[36] "Further, only a few crews were trained to deliver nuclear weapons, and standards of training and vigilance were not unusually high." No entirely new post-war bomber aircraft became operational until late 1948 when a B-36 was delivered to SAC; and the first all-jet B-47 was delivered in December 1950.

Finally, we can only speculate on what was the weakest link of the early atomic forces. Only a dozen U.S. A-bombs existed through April 1948 according to General Spaatz. Another report puts the July 1947 stockpile at no more than 29 weapons; another gives 120 by November 1948. George Quester has said that "in the fall of 1948 warhead output apparently had not yet hit the one-a-week rate a newspaper columnist had conjectured, which meant that the American stockpile might still be well under 150 warheads, and perhaps under 100."[37]

Hence the ability of the new Strategic Air Command to deal a decisive death blow to the USSR seems more dubious than florid contemporary rhetoric claimed. Moreover, even had the offensive wherewithal for this task been in hand and in good working condition, it is not clear that intelligence capabilities could have supported precision attack target planning. Relying on Tsarist maps and the products of a large Soviet cartographic effort in the 1920s and 1930s (which had fallen into German and then U.S. hands), planners set to work developing attack profiles and simulated radar target pictures. However, Soviet cartographers often had simply recopied old Imperial maps, and their tracings tended to be shoddy. In any case there was no way of linking up the maps into a full target grid. The United States did obtain German aerial photography of 47 of the 70 largest Soviet cities, and gained access to Japanese reconnaissance of one more. But probable position error was on the order of thousands of feet for most cities, and several miles for others. Probable distance errors were even worse. Bomber route error budgets also had to include generous allowance for contemporary navigation techniques.

Furthermore, as SAC began to prepare target folders for likely Soviet objectives, it was discovered that, except for a few large cities, economic and other intelligence of interest was unavailable, obscure, or contradictory. In the Autumn and Winter of 1941, to give just one cause for this, 1,300 large war plants--including large fractions of key Soviet war supporting industries--were evacuated from the Nazi advance. Continued plant siting in the Volga-Don basin and east of the Urals continued through the war and new "prefab" Soviet industrial facilities were constructed in large numbers through the 1950s.[38] Deficiencies in target and economic intelligence alone could spell the downfall of precision targeting, not to mention the fact that accurate analysis of economic vulnerabilities required thorough--but at the time <u>probably</u> unavailable--knowledge of management, transportation and other characteristics of the Soviet economy. Some ingenious reconnaissance and intelligence collection programs were eventually implemented to resolve these problems, but the size of the task far exceeded contemporary technical capabilities.

As if these deficiencies were not serious enough, some questioned the basic tenet of economic targeting. After all, the USSR seemed first and foremost to be a rural nation. Could even ideal atomic air power "break the back" of a relatively primitive economy? The prospects looked bleak: Hitler had captured the most economically developed parts of the USSR, and although the Germans' ability to strike beyond the front was limited by lack of air power and partisan organizations, the Nazis did destroy perhaps a quarter of the value of prewar Soviet fixed plant. Soviet losses look even worse in light of the gruesome

statistic, only admitted by Khrushchev in 1961, that Soviet fatalities during the Great Patriotic War had run to twenty million.[39] True, that damage was accomplished over several years and some allied aid had been forthcoming. But the Germans simultaneously forced the Russians to commit a huge fraction of their output to the land war. Facing far fewer NATO divisions, the Soviets could devote that much more production to liquidating the effects of bombing.[40]

Finally, the USSR surprised the West with the quality and vigor of its air defense effort. "The Russians over this period had begun allocating considerable sums of money to an air defense radar warning system, largely dependent at first on captured German technology, and to a force of jet interceptors."[41] The new MiG-15 jet interceptor, superior with respect to maneuverability and other characteristics to the comparable USAF F-86, entered service in 1948, and Soviet radar technology came along at a brisk pace. It was intended that SAC bombers would penetrate in large "cells" (with one or two planes carrying bombs and the rest acting as decoys and defensive escorts).[42] Despite the defensive armament and numbers of targets in cell, however, new data on Soviet defenses indicated that B-29s and B-50s (which had to fly at altitudes high enough to be detected easily and which were in any case slower than jet interceptors) would face growing problems penetrating Soviet defenses as the latter matured.

Many programs were undertaken to enhance SAC penetrativity, including efforts to develop parasite and long-range escort fighters to accompany the bombers, but these programs were not successful. An alternative was nighttime penetration of Soviet defenses. As noted,

however, early blind radar bombing performance left much to be desired. At the very least, in sum, Soviet air defenses could have jeopardized SAC's ability to destroy specified targets in daytime, by attrition, or at night, by reducing U.S. aiming accuracy. (Indeed, on 6 March 1947, General Wheeler speculated that the objective of Soviet air defense system was "to reduce U.S. confidence in our ability to penetrate Soviet defenses, reducing the possibility that the United States would undertake a preemptive first strike against the Soviet Union even under extreme provocation."[43])

Glaring though they might have been, these operational and materiel deficiencies only marginally influenced force and weapons requirements. In fact, these problems, which seem now to have been serious enough to threaten totally the success of operations, did not seem to force the slightest accommodation by the vertical bombing theory. Debate and planning continued to overlook narrow but crucial questions of feasibility and focussed instead on the role an unchallenged "effective" deterrent should play in the framework of overall U.S. defense. So long as operational difficulties only led to apparently more demanding force requirements and not to strong rationales for change or adaptation in concepts and strategy, then the requirement for an absolute deterrent could form the justification for almost unlimited strategic air forces. Under the vertical bombing theory, a case for huge forces to accomplish even relatively limited military objectives could be made. The perceived need for such a large and reliable force above all competitors was directly to mold the force development, and indirectly foreign policy, over the next decade.

IV. THE THERMONUCLEAR SOLUTION

For reasons discussed in great detail elsewhere, by 1953 the United States had chosen to foreclose the option of adequate conventional defense even for NATO. American planners had slowly conceded that atomic air power would be central to the defense of the United States and its worldwide interests. As prospects for conventional defense dimmed, the atomic might of the Strategic Air Command assumed an increasingly broad role in the national defense posture. Consequently, efforts were begun to bring contingencies on both the European and Korean models under the aegis of the atomic deterrent.

Ironically, anxiety about the adequacy of the nuclear deterrent intensified even as the nuclear potential of the U.S. began to improve dramatically. After 1951, bomb inventories boasted smaller, lighter and more reliable weapons incorporating superior ballistic, handling and other properties. SAC manning more than doubled between 1950 and 1954. The U.S. overseas basing system grew rapidly following upon a string of alliances with nations along the periphery of the Communist Bloc. During the decade of the 1950s, the number of SAC Main Operating Bases would more than triple. SAC was also to move from a no-jet force in 1950 to an all-jet force in 1959: the operational strength of the Command (PAA) doubled over the decade.[44] Navy jet carrier aircraft began to join the nuclear arsenal as well.

Most importantly of all, of course, bomb yields and stockpile size began to grow sharply after 1950. An apparent shortage of domestic Uranium ore was relieved by an artificial doubling of prices for low-

grade U.S. yellowcake: subsequent discoveries of large reserves in North America liberated the United States from its reliance on African imports by 1951. Decrepit production reactors were replaced, and a supply of material for testing improved implosion bombs was laid aside.[45]

Bomb design research of the late 1940s began to pay off too. According to Rosenberg, "proof testing of the new Mark IV implosion mechanical assembly and new nuclear implosion cores, which made more efficient use of plutonium and U-235," had been approved in June 1947.[46] The SANDSTONE tests to validate these improvements took place in the Spring of 1948 and they "promised a large stockpile of new weapons, which were cheaper, smaller, had a wide range of destructive force, and used much less fissionable material than the original A-bombs."[47] In fact, the average yield of the SANDSTONE shots was 35 KT, more than double the power of the earlier CROSSROADS test and the wartime bombs.[48] If the new weapons used half the material of the earlier weapons, to deliver twice the yield, here was an opportunity for quadrupling the explosive potential of the U.S. arsenal. The next set of proof tests for improved weapons technology, the GREENHOUSE series in April and May 1951, seemed to redouble U.S. potential overnight:

> The more sizable breakthrough in nuclear weapons production was to come only in 1950 and 1951, with a new series of tests demonstrating that fissionable materials could be more efficiently used, so that twice as many bombs might perhaps be produced from a given amount of uranium or plutonium. By 1951, estimates at last were circulated that the United States stockpile had grown to 750 or more weapons, which represents a considerable rise over the 200 a steady three-a-month production rate after 1945 would have turned out.[49]

As noted above, U.S. nuclear planning through 1949 had been conducted over short-range horizons. It appeared in 1951, however, that the U.S. would achieve well ahead of schedule its initial JCS long-term stockpile offensive. In some sense, the United States would have then achieved atomic sufficiency, at least according to prior criteria. Now, the earlier questions of force sizing and employment returned as planners contemplated a revised definition of atomic sufficiency. Basically, at this point the United States stood at the crossroads of the force and employment linkage.

There were two key aspects of this juncture as regarded the future connection of forces and missions. First, what was nuclear bombardment supposed to accomplish and, second, how much capability was necessary to attain given war goals? The former question was analogous to the debate held over the roles and missions of strategic air power through the end of World War II. The latter question concerned force size and the overall scale of effort which should be devoted to the goal of strategic nuclear air power. A sound linkage, however, was sabotaged by the elevation of strategic bombing to the first line of American defense. As noted, this decision led to the justification of huge stockpiles and lavish outlays to ensure SAC's reliability.

The answer to both this heavy responsibility and to exasperating operational difficulties was to continue to expand the scope of the admissible Soviet target system. U.S. strategic offensive planning through about 1950 had concentrated on central city urban/industrial conglomerations. But the so-called Harmon Committee's official recommendations for expanded (countermilitary, counternuclear, and

interdictive) targeting introduced a new component into U.S. nuclear force planning. There obviously was a point beyond which adding more weapons to a counter-city reserve began to face what seemed to contemporaries to be diminishing marginal returns. On the other hand, if targets above and beyond cities were inventoried, the size of the necessary stockpile could get totally out of control.

In this way, U.S. force requirements expanded sharply. As the economic targeting theory of the precision bombing school held that damage criteria must be satisfied with very high confidence, the destruction of important individual targets (and not target conglomerations or undifferentiated floor space) was critical to the success of an air campaign. Insofar as a true vertical campaign should also be directed against a large number of targets, a precision bombing offensive can generate requirements for large forces, <u>even if</u> the air war is subordinated to land objectives. When major reliance is placed on air power, force demands proliferate even more. Thus, in 1947, 400 weapons were deemed sufficient. In 1950, the number had grown to 1,000. General Vandenberg speculated in 1952 that perhaps 6,000 Soviet targets would have to be destroyed to wipe out the USSR.[50] If U.S. requirements became more ambitious or if sources of uncertainty in offensive planning grew at all, then the meaning of adequacy could be perturbed beyond even this requirement.

Air planners have always recognized that the likelihood of success of the campaign can be increased either by improving target intelligence, economic models, and weapon performance or by expanding the attack. To this latter end, we can allocate extra sorties, increase

the probability that each sortie produces required damage, or expand the scope of targeting. This requirement for severe damage across the entirety of a large Soviet target system was not only to be satisfied by rapid improvement of the atomic force. In addition, the incentive to increase damage expectancies proved one of the most attractive features of the hydrogen bomb.

Thermonuclear weapons solved many of the problems that threatened the success of sophisticated bombing campaigns, in particular, economic bottlenecking campaigns. When targeting became more complex, as it did after 1951 on account of force growth, the H-bomb dissipated any continued doubt that the aims of a vertical bombing campaign could be fulfilled. The hydrogen bomb did so by removing the technical obstacles to precision bombing discussed above.

In terms of the partitioning of their energy, atom and hydrogen bombs are not so technically different that each would be needed for the sake of complementarity of special lethal effects (except for high neutron and X-ray output for which thermonuclear weapons are more appropriate). When speaking about destructive effects against structures, the two weapons are relatively similar. The difference, of course, is that an H-bomb can be made to yield to very high power levels while an atom bomb is less efficient in higher yield applications.[51]

Nonetheless, why require megaton-range outputs in the first place? After all, in the late 1940s analysis identified proper atomic bomb yield goals to fall in the 30-100 kiloton range. An optimally fuzed 10 MT weapon will damage housing and unhardened structures through a radius of more than 9 miles (compared to a radius of about 2 miles for a 100

KT weapon). But in the multi-megaton case, 275 square miles of coverage begins to approach in area some of the larger American urban areas and it exceeds the extent of nearly all Soviet cities. For smaller towns and isolated economic installations, the degree of "overkill" is even more dramatic. So went the reasoning in some parts of the U.S. technical community at the time the decision to go with the "Super" was being made. Arguing that megaton-range weapons wasted excessive power, some scientists recommended a more moderate compromise device:

> In November 1952, the U.S. tested a very powerful fission bomb, with the code name KING, that had an explosive yield of 500 kilotons. Its purpose was to provide the U.S. with an extraordinarily powerful bomb by means of a straightforward extension of fission-weapons technology.[52]

Those scientists on the AEC's General Advisory Council who were interested in developing an alternative to the thermonuclear device argued that weapons like KING were themselves "big enough to take out a large area," i.e., a whole city. Such a weapon, according to its proponents, could satisfy any conceivable military requirement.[53] Whether this weapon was intended as a backup or as a substitute for the hydrogen bomb is obscure, given the vigorous attempts by many of the scientists involved to cover up *ex post facto* on the matter of the "Super." The facts of interest to us here are that the decision to go with the H-bomb allowed operational planners a solution to a galaxy of technical problems that bedevilled U.S. planning for an effective precision atomic bombing offensive.

As it was, by the time of the KING test, the cat was already out of the bag. The thermonuclear breakthrough first was demonstrated at test

GEORGE, series GREENHOUSE.[54] The first wet thermonuclear device, MIKE, (series IVY), was fired at Eniwetok in October 1952; the first dry weapon BRAVO, (series CASTLE), was exploded in February 1954. The BRAVO weapon yielded far beyond the power expected. The 15 megaton blast demonstrated strikingly its potential for obliterating large urban areas. Further, the shot distributed lethal fallout to unimagined distances downwind: the peak radiation dose rate 175 miles away, for instance, was a whopping 100 rem.[55]

The H-bomb did not signal the obsolescence of fission weapons: it merely made it easier to destroy certain elements of the possible nuclear target system. Availability of materials was not unlimited, and early high yield thermonuclear weapons could only be carried by the largest bombers in the force. But the BRAVO test did portend a dramatic change in the possible course of a nuclear air offensive. As regarded the raft of targeting problems facing planners, in fact, the most significant effect of the H-bomb was to undercut dramatically requirements for improved U.S. intelligence and other operational refinements which would have been needed to guarantee the successful pursuit of an articulated target doctrine using only the relatively low yield atom weapons available before 1954.[56] The hydrogen bomb erased positional distinctions between targets, and minimized the significance of geodetic and other forms of reference bias. Rather than be forced to pick among two nearby targets, a big weapon could be laid down without painstaking regard to precise aim point tradeoffs.

Another favorable consequence of the hydrogen bomb was the dissolution of uncertainties about target coverage in metropolitan

target conglomerations: thus it was less necessary to worry about which specific target "types" should be ranked more highly than others for the sake of preparing guidance for war plan aims. Not only because of its superior yield-to-weight characteristics, but also because of its higher range of yields, the H-bomb also made possible the then new and inaccurate ballistic and cruise missile concepts as viable weapon systems. For, on account of poor aiming precision but high yields and "in the absence of good targeting information, any missile exchange could involve the Americans in city busting whatever their inclinations."[57] Fine targeting accuracy was an "illogical requirement" to contemporary weapon designers.

To show just how dramatic the technical possibilities for resolving the traditional operational difficulties that undercut the chances for successful precision attack then became, consider the implications of large yields for both area and precision target coverage. A 20 MT weapon (somewhat larger than the demonstrated yield of the BRAVO weapon), fuzed more or less correctly, will damage housing and unhardened structures through a radius of about 12 miles. The area subject to this blast coverage (425 square miles) just about exceeds the area of all Soviet cities.[58] For instance, Moscow (see Figure One) is by far the largest single target area in the USSR: still it is only about the size of Baltimore. A 20 MT weapon that can be delivered with a CEP of five miles or better would have an excellent chance of demolishing the city. Two or more reliable weapons on target would almost certainly destroy everything that was not deliberately hardened against high blast pressures and radiation. And if hardened targets

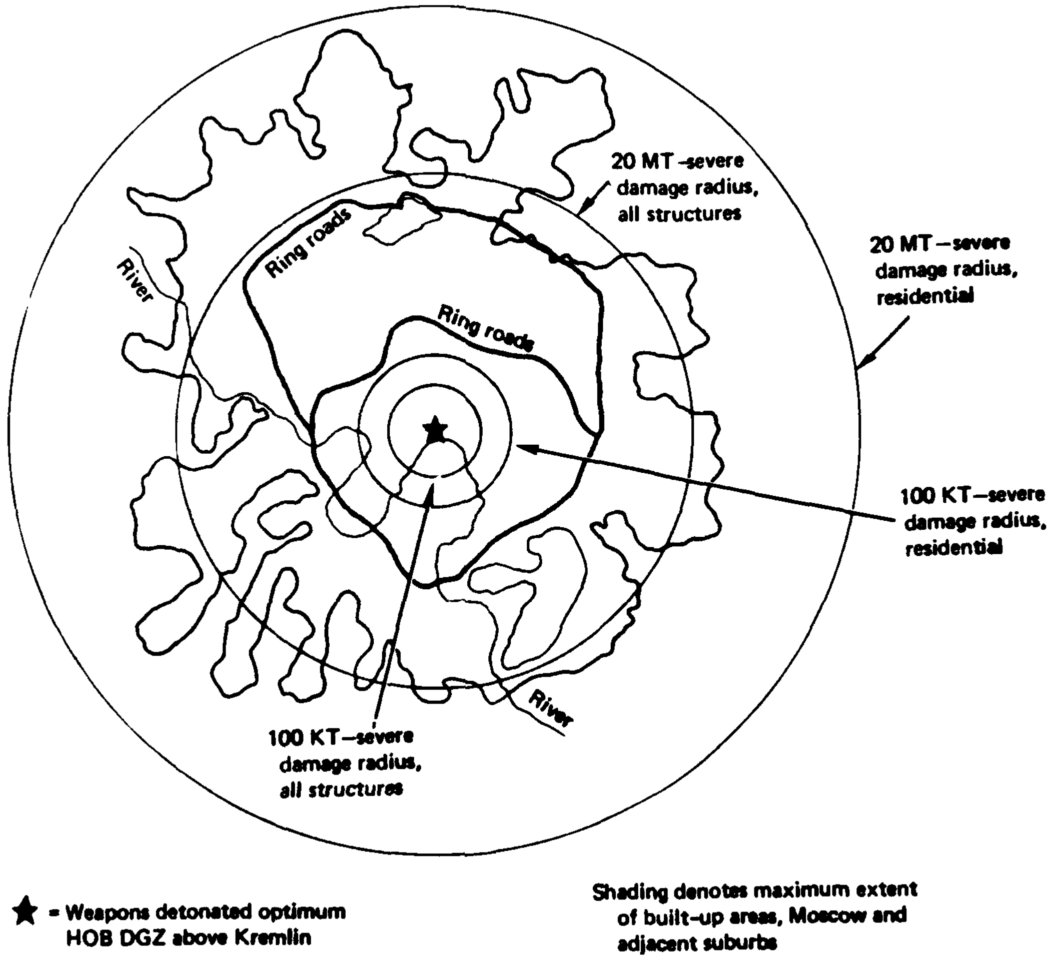

Fig. 1 — Impact of thermonuclear weapons on U/I coverage: Moscow

were present, the blast power necessary for their destruction could nearly always be applied simply by adjusting bomb aiming points. In this way, the key effect of the H-bomb, a most salutory one from the point of view of U.S. targeteers, was reduced uncertainty.

This improved confidence is quantified by an illustrative attack portrayed in Figures Two, Three, and Four. As a typical urban area target, assume a circular region of 300 square miles. Within that city there are six equidistant targets located at the vertices of a hexagon centered on the hub of the city. Each specific target requires 15 psi for destruction. The remainder of the area is considered soft from a targeting standpoint, that is, other targets are considered to have hardnesses of 5 psi. As Figure Two shows, each of the special priority targets is about two and one half miles from its nearest neighbor.

Suppose first that our objective simply is area destruction. Given that the net on-target reliability of each explosive is 0.8, then what is the probability that we could cover the area with five psi? Figure Three shows the advantage of the large weapon for the area coverage mission, given a desired damage expectancy of 0.8. The high yields of the big thermonuclear weapons in this case essentially neutralize sources of aiming inaccuracy. To the contrary, we must use many more of the smaller atomic weapons here to achieve the same coverage. This relationship brings to mind the old bromide of the early H-bomb debate, "like it or not, the megaton bomb is a city buster."

The H-bomb _de facto_ finally rendered the distinction between terror and precision bombing obsolete. U.S. planners never admitted a goal of "busting cities," but the collateral damage inflicted by such big bombs

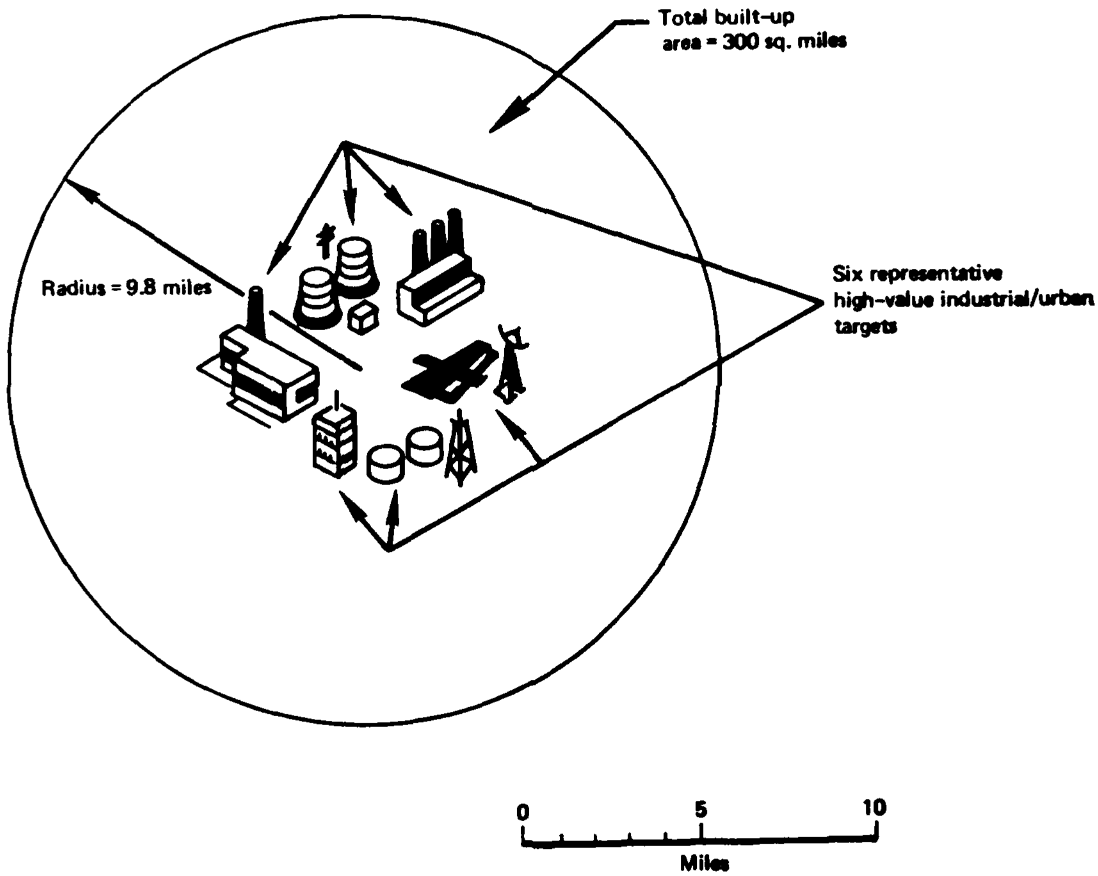

Fig. 2 — Hypothetical soviet urban / industrial target conglomeration

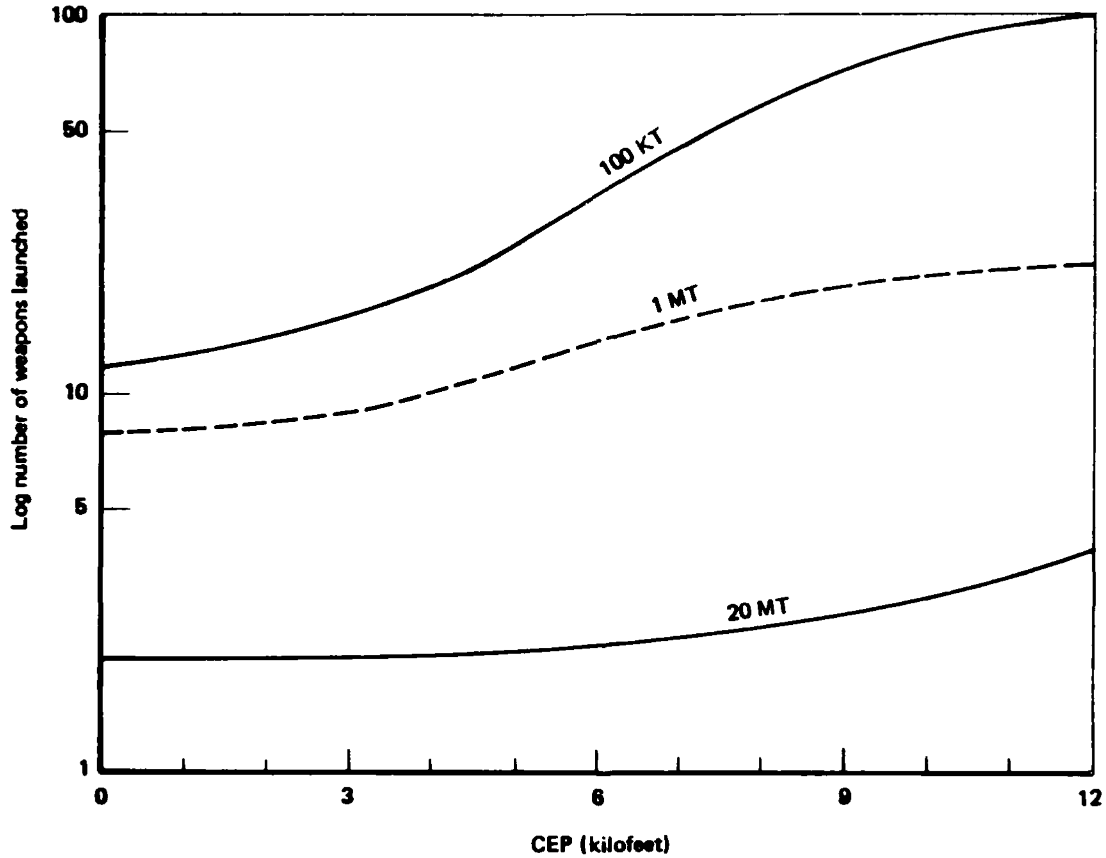

Fig.3 — Impact of thermonuclear breakthrough on weapon requirements for area concentrations

did indeed ensure that an attack would pick up just about every conceivable target in the area under attack. Although the "principal intended targets for U.S. nuclear weapons have always been military targets," said Professor Henry Rowen, "the invention of thermonuclear weapons and the introduction into the American force of very large yield weapons meant that it was in many cases virtually impossible to single out military targets or selected war industry, with weapons delivered quite inaccurately, without killing very large numbers of people."[59]

However that may be, the United States continued to target urban/industrial conglomerations, at least in principle, on the basis of the precision objectives strategy. Therefore, the area coverage effectiveness, as portrayed in Figure Three, may overstate the advantages of increased firepower somewhat. We accordingly turn to an analysis of coverage of individual targets given the same assumptions.

Figure Four shows the implication of megaton-range bombs for coverage of the six precise aimpoints in the city. That figure shows the number of weapons which must be allocated to our U/I conglomeration to assume an overall probability of desired damage on those designated targets of 0.8. Clearly, the H-bomb simplifies the target coverage problem immensely. Fewer weapons and delivery vehicles are required for the job. Most important to missile and weapons designers, for high yield weapons good CEPs seem to be essentially irrelevant to mission success.

All in all, given technical and other constraints on the U.S. forces of the 1950s, it is easy to understand why the H-bomb was an attractive addition to the U.S. arsenal, even given continued

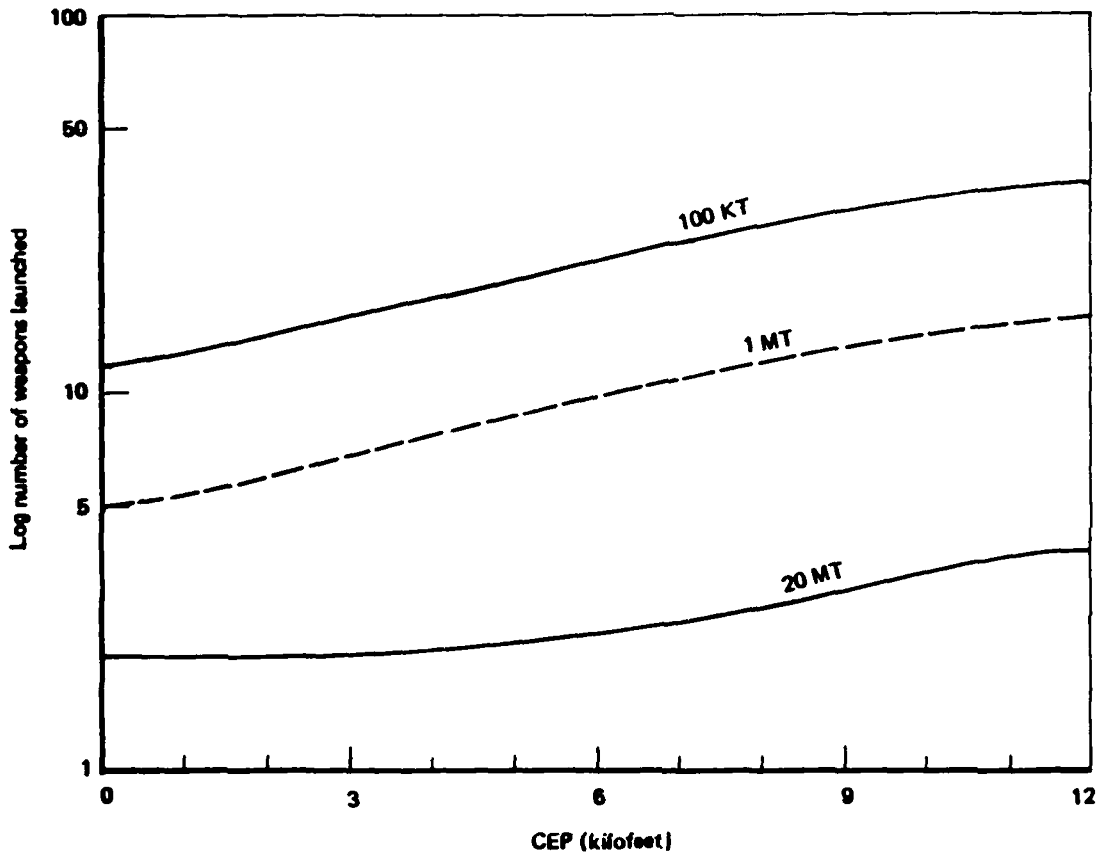

Fig. 4 — Impact of thermonuclear breakthrough on weapon requirements for precision installation coverage

theoretical devotion to the vertical targeting objective. The H-bomb guaranteed good "probabilities of kill" and in so doing freed up smaller weapons for "tactical" use and for other targets which were by 1954 starting to flood strategic target inventories.

In exactly the same way, not only did thermonuclear weapons undercut difficulties with weapon system availability, reliability, and delivery accuracy, they diminished the significance of SAC pre-launch survivability and SAC victory in the air battle If fewer weapons were required for the destruction of targets, fewer surviving sorties would be necessary to do the same job.

Figure Five illustrates the ability of a hydrogen-bomb equipped attacker to destroy a target with many fewer successful sorties arriving. Shown are the number of weapons that are required to develop a 0.80 damage expectancy on a target given a single shot probability of kill and the number of weapons required to destroy a target complex. Say that five weapons are needed to wipe out urban/industrial complex (see the line noted "[5]"). Then, if each bomb's SSPK is 0.50, about 17 bombs are required for the area. But if a single city-buster can get all five targets, only about four weapons will (statistically) be required, given independent and identically distributed bomber penetration probabilities.[60] Therefore, higher yields meant that cross-targeting for fixed desired damage expectancies would be simpler and would require fewer aircraft for each target.

There are other indicators of enhanced effectiveness due to higher yield that we might call on but it is clear from this simple inspection of coverage and survivability issues that the hydrogen bomb had a

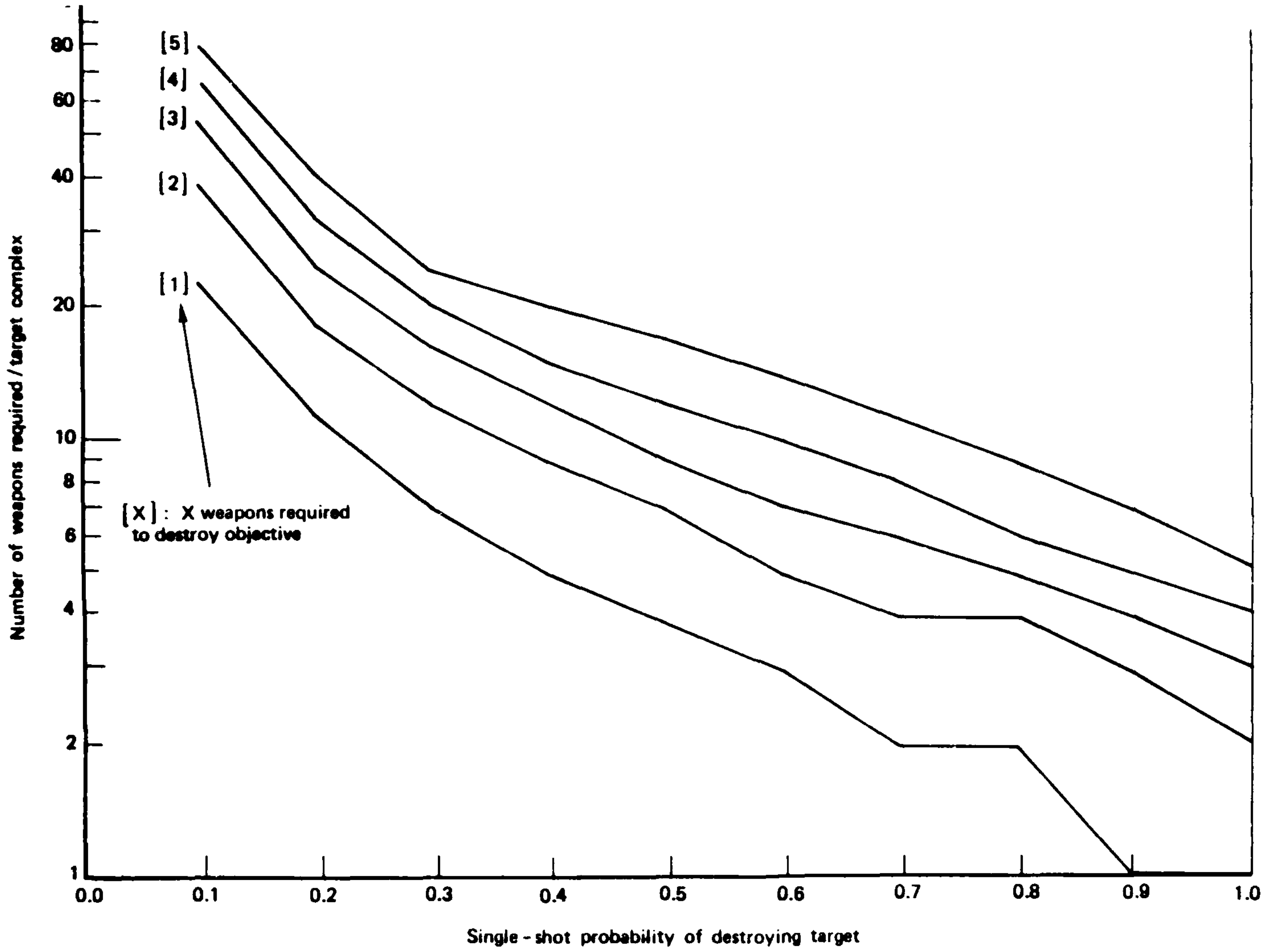

Fig. 5 — Implications of thermonuclear weapons for sortie survival (damage goal = 80% of target destroyed, expected value; delivery reliability = 0.8)

profound effect on SAC operations as conducted then. The bomb's extravagant explosive power was, to a large degree, wasted. But the bomb increased markedly the effectiveness of a force of given size. High yields enabled SAC to surmount severe intelligence and other theoretical problems, and to free up sorties, allowing broader targeting. In short, the H-bomb justified a bombing theory that was, for good reasons, moribund by 1950. In this way, it came to have a dramatic and an enduring effect on U.S. defense policy.

V. CONSEQUENCES AND CONCLUSIONS

As a result of this technical *deus ex machina*, which seemed to endorse beyond doubt the view that strategic bombing could be an independent line of defense, U.S. strategic planning throughout the 1950s became increasingly disconnected from traditional military preparations. The parallels between the changed nature of nuclear air power when only atom bombs were available and following thermonuclear breakthrough, and the sharp differences between theoretical air power musings of the 1930s and actual World War II experience are striking. They attest to the potential for operational trouble if force and employment planning are severed.

As was the case in the years before World War II, in the 1950s bombing became first a instrument of strategy and then a strategic end in itself. When faced with changes in the operating environment, plans were readjusted in light of theory not experience with the net result being that the posture came to be even more inappropriate. According to the canons of classical bombing theory, each increment to the force structure and war plans made excellent sense. But because the entire posture was based on the independent concept of vertical bombing, the strategic posture became increasingly distorted within the broader context of national security requirements.

Consistent with this doctrine, American air power proponents felt that atomic bombing could win a war promptly and without major investment in conventional forces. The financial dividends, not the apparent military and deterrent value, of the precision air doctrine

explain its ready embrace by the Eisenhower administration. Measured in Fiscal Year 1982 dollars, U.S. investment in strategic forces (excluding the costs of nuclear weapons) between fiscal years 1951 and 1961 amounted to $400 billion, fully 21% of all DoD authority over that time (even including Korean War related general purpose force outlays). This generous funding fueled a phenomenal increase in SAC operations and investment, shown in terms of relative growth of activities and effort in the following table.[61]

TABLE ONE. GROWTH RATE OF THE SAC POSTURE (FY 1950 = 1.00)

Fiscal Year	Active Aircraft (Bomber/Recce:PAA)	Personnel (SAC)	Flying Hrs (SAC)	Opl Bases	Spending on Strat Frcs
50	1.00	1.00	1.00	1.00	1.00
52*	1.63	1.26	4.39	n/a	4.53
54	2.32	1.40	5.43	1.59	2.07
56	2.99	1.84	8.14	1.74	3.62
58	3.08	3.10	8.96	2.09	3.92

[* Excludes Far East Air Force operations]

True, this ambitious and costly buildup enabled the United States to enjoy a remarkable nuclear lead over the Soviet Union. Indeed, SAC during the 1950's is without competition as a military example of capability, readiness, proficiency, and morale. As well, it can be argued that massive U.S. superiority did on some occasions prevent the precipitation of Soviet challenges.

But the wholesale endorsement of strategic forces and doctrine had serious side effects. The posture failed to head off subversive and insurgent threats to U.S. and allied interests. It can also be argued that the U.S. posture of that era encouraged nuclear proliferation by some U.S. allies and dissuaded them from investing in suitable general purpose force postures. It is known that even the U.S. leadership had,

by 1957, begun to think in terms of ultimate parity in the strategic balance, a recognition that could spark concomitant erosion in whatever one-sided deterrent value that the U.S. might have in some way enjoyed until that time.

Most important for our purposes, however, the experience of this decade of strategic planning had a far-reaching effect on the design of U.S. nuclear forces from the 1950s to the present. For example, the massive deterrent doctrine that was developed over the decade from the roots of precision air power required that U.S. weapons be launched right away: first, to avoid preemption; second, to hit mobile targets (especially ground forces before they moved away from locatable aimpoints); and third, to ensure that attack results would begin to affect nontargeted components of the enemy's military capability as quickly as possible. Naturally the tactics and concepts that were selected to fulfill these goals could be justified given the assumption that nuclear bombardment was to play the leading, if not sole, role in major war. These and related attributes of employment planning were for the most part "written in stone" and their persistence today is a cause for substantial concern.[62]

The implications of these developments for subsequent generations of defense planners is crystal clear in hindsight. The results of the subsequent self-reinforcement between the force structure and policy for the nuclear forces are well-known. In the case of SAC in the 1950s, we can see several striking illustrations of the strategic air solutions endorsed by the H-bomb that plague us today: a force which could not be withheld, a force which had to be launched early on (perhaps not first,

but definitely not second), a force in which discrimination between targets and non-targets was very difficult, and a force which could not be reliably managed and controlled once it was generated in a crisis.

A major related impact of the U.S. reliance on a massive deterrent posture can be seen in the history of U.S. general purpose force planning. Between 1945 and 1949, nuclear weapons were for the United States an acquired taste. During and after Korea, amplified by the seeming H-bomb cure, they became an "addiction."[63] As the scope of conceivable target lists expanded after 1952, the threat of general attack became the Eisenhower strategy of massive retaliation, known widely as the "New Look." Promulgated officially by Secretary of State Dulles in January 1954, that doctrine was based on "a great means to retaliate, instantly, by means and at places of our own choosing."[64] The new strategy called for the destruction of the "entire Soviet target system in one massive blow."[65] In short, the adoption of this strategy had a dramatic impact on weapon requirements as viewed by the three services. For instance, one manifestation of the new coverage requirements was the inclusion of tactical objectives in general war plans. Another manifestation was the orientation of U.S. general purpose forces to short nuclear wars.

Because of the strategic nuclear planning disconnect, it has not always been clear what specific problems have been. Though today they may be clear, as a result of the severed planning linkage, the immediate contemporary cause of difficulty may be opaque. By choosing a non-discriminating path for policy-making, the United States in effect became locked into a set of policies, forces and missions. By virtue of

the resources invested in U.S. strategic nuclear forces and the U.S. reliance on a general war strategy, among other factors, American strategic forces came to be disconnected not only from their targets and the militarily relevant capabilities represented by those targets but also from the likely contingencies within which the use of nuclear weapons might have become a credible option. Given the disconnection of the budget and forces and the chasm between policy and employment plans and forces, the United States' strategic nuclear forces could only by chance be the tool upon which the President would wish to rely in emergency. The force structure as it developed in the decade of the 1950's slowly accreted in a way to block opportunities for change. Specifically, the Operations and Personnel costs of the large bomber fleets of the 1950s were sufficiently high that each aircraft would duplicate in support expenses its procurement costs within a very few years. This would proscribe in advance funding which might be used for other defense activities.

This has had a large impact, as noted, on the alliance and diplomatic relations of the United States. True, the United States' strategic air force posture throughout the 1950s was a relatively "stable" one from a planning point of view. In this respect, perhaps the U.S. one-purpose strategy did confer a substantial degree of flexibility. For example, once Soviet air defense forces had been suppressed, U.S. aircraft could operate more or less at their leisure. Bomber forces could attack a broad mix of targets, regroup and exploit reconnaissance, organize target restrikes, and so on. In short, the prelaunch survivability of aircraft could be good; their penetration

prospects excellent once the Soviet strategic air defense force, PVO Strany, had been annihilated; and the so-called yield/accuracy combination for big bombs delivered from manned aircraft would ensure as good a probability of kill as could be hoped for.

However, if stable, the picture was still not attractive. I have listed some of the consequences of this fracture here: inertia in strategy, suppression of the general purpose forces, diplomatic difficulties, to name a few. These exist in varying degrees of intensity today. The adverse consequences of the problem, though, seem to haunt strategic employment planning the most. Indeed, the reification of the EOU targeting scheme can be seen today in the JSTPS organization, one division of which prepares the plans, the other the target list. The U.S. emphasis on targets, as opposed to capabilities, flexibility, ad hoc option preparation, and so on, directly underlies the historic U.S. failure to incorporate adequate agility into the U.S. nuclear force posture.

When he took office, Secretary of Defense Robert S. McNamara attempted in particular to move away from the inflexible, general war nuclear posture of the 1950s. McNamara's planning reforms had three components. First, reliance on nuclear weapons to the exclusion of other options was held to be imprudent. Such an approach could preclude appropriate and effective American response in crises where countervailing deterrents based mainly on nuclear threats might not be credible. Moreover, it was not clear to McNamara that NATO's members were so weak and poor that the Alliance could not hope to muster an effective conventional defense of its own territory. Second, many

within the Kennedy Administration agreed that nuclear proliferation was highly dangerous and should be suppressed if at all possible. The spread of nuclear weapons among NATO countries might not only enhance the likelihood of war, it could also undermine collaborative efforts to build a strong conventional defense. Third, it was deemed necessary to introduce more flexibility into U.S. strategic war planning. In planning for, say, a European scenario, this meant that the United States should not be compelled either to launch a massive retaliatory strike against the USSR or else to do nothing. Rather, the U.S. should be ready to reply at whatever level was appropriate. This, it seemed to McNamara and his advisers, probably was the only way that nuclear weapons might be integrated into Allied defense without foreordaining large scale civilian destruction in all the nations concerned. These proposals met, as history informs, with an unfortunate fate at the hands of an audience fed on a disconnected air power diet. As a result, McNamara retreated by means of a cost-effectiveness expedient from which we have tried, since the early 1970s, to extricate ourselves. However, the progress towards this end has been painfully slow. In conclusion, then, in a very real sense, the U.S. failure to tie the hydrogen bomb to strategy is responsible for at least a share of the blame for these other pressing problems.

ENDNOTES

[1] Cited in Samuel Huntington, The Common Defense, Columbia University Press, New York, 1962, pp. 89.

[2] On the air power theorists generally, consult Bernard Brodie, "The American Scientific Strategists," Rand Paper P-2979, Santa Monica CA, Oct. 1964, p. 23.

[3] See the present author's "Planning Nuclear Defense: Force Structures, Employment Plans, and National Objectives," unpublished Ph.D. dissertation, Department of Political Science, Massachusetts Institute of Technology, 7 November 1980, chapter III. (Book forthcoming).

[4] Perry Smith, The Air Force Plans for Peace, 1943-45, The Johns Hopkins Press, Baltimore MD, 1970, p. 16.

[5] See tabular displays in Sir Charles Webster and Noble Franklund, The Strategic Air Offensive Against Germany, Volumes I and IV. London, HMSO, 1961.

[6] British combat results were grossly at odds with prewar analyses on the probable effects of conventional bombing. Based on often freak events informing World War I, Spanish Civil War, and other data, projections of the consequences of conventional bombing were overestimated by a factor of 30 to 50 or more. See George Quester, Deterrence Before Hiroshima, Wiley, New York, 1966. In operational experience early in the war when the RAF still pursued precision objectives, for example, it was determined that only about 20% of all bombs dropped by RAF during daylight hours fell within five miles of their targets. Henry S. Rowen, "Formulating Strategic Doctrine," "Commission on the Organization of the Government for the Conduct of Foreign Policy," Volume IV, Part III, Washington DC, June 1975, p. 221.

[7] See Fritz M. Sallagar, The Road to Total War, Von Nostrand, Reinhold, New York, 1969, for a discussion of some of the U.K.'s World War II bombing objectives.

[8] On 30 May 1942, Bomber Command attacked Cologne in the first "thousand plane raid." Six hundred acres were destroyed in the attack, and Sir Harris used this example as "proof" that area bombing could quickly destroy as many German cities as was necessary. However, the heavy damage done in this case was due to the particularly dense nature of the city and its undue vulnerability to incendiary attack. The dramatic effects of the Cologne raid, it should be noted, were seldom repeated in subsequent raids.

[9] Herbert Goldhamer, "Reality and Belief in Military Affairs: A First Draft," Rand R-2448, Santa Monica CA, June 1977, p. 74.

[10] Fearing that the Americans would redeploy forces to the Pacific,

the British eventually dropped the point. For the USAAF-RAF dialogue, see Thomas Coffey, Decision Over Schweinfurt, David McKay, New York, 1977.

[11] Haywood Hansell, The Air Plan That Defeated Hitler, privately published, Atlanta GA, 1972; and Carl Kaysen, "Note on Some Historic Principles of Target Selection," Rand RM-189, Santa Monica CA, 15 July 1949, p. 9.

[12] On the paradoxical "reverse morale" effect, see R. M. Titmus, Problems of Social Policy, London, HMSO, 1950, and also P.M.S. Blackett, Fear, War, and the Bomb: The Military and Political Consequences of Atomic Energy, Whittlesey House, London, p. 23 and p. 216. As to the industrial consequences of bombing, for one example, Blackett uses the following German war production figures in his argument against the value of bombing in World War II (index based on output in 1940 before bombing began in scale): 1940=100; 1941=101; 1942=146; 1943=229; 1944=285.

[13] Fred C. Ikle, The Social Impact of Bomb Destruction, University of Oklahoma Press, Norman OK, 1958, pp. 16-17. Mortality rates per square mile of cities under heavy bombing attack attest to the greater casualty producing capability of the atom bomb. For Tokyo, the figure was 5,200 deaths/sq mi, for Nagasaki and Hiroshima, the value was 20,000 and 15,000 respectively. The A-bomb dropped on Hiroshima caused about 4 square miles of heavy destruction and about ten square miles of moderate to heavy destruction to housing. USSBS, "The Effects of Atomic Bombs on Hiroshima and Nagasaki," Chairman's Office, 30 June 1946.

[14] Delays in the onset of bombing effects unfortunately have been the rule in bombing history. For example, when queried by Washington about the likely lead-times in bringing the Pacific war to a close by means of bombing, General LeMay, whose 20th Air Force attacked Japanese targets after January 1945 mainly in the Congreve style, acknowledged this crucial shortcoming:

> He [Arnold] asked the question: When is the war going to end? Well, we had been so busy fighting it that we hadn't thought about a date for the end but we went back to some of the charts we had shown him about the rate of activity, the targets we were hitting, and it was completely evident that we were running out of targets along in September and by October there wouldn't really be much to work on except probably railroads or something of that sort. So we felt that if there were no targets left in Japan certainly there wouldn't be much war left. So that was the date we gave him.

Cited in Len Giovannitti and Fred Freed, The Decision To Drop The Bomb Coward-McCann, New York, 1965, pp. 34-35. Note here that in FETO, bombing played a different role, much more in the model of naval blockade than as an "independent" war. U.S. air strategy in the Far East was at times more like RAF bombing than the 8th/15th Air Force

philosophy. At first, bombing on Japan and throughout FETO emphasized tactical targeting objectives. However, that approach changed sharply as U.S. basing availability improved in the Pacific. The subsequent essentially "area attacks" by the 20th Air Force on the home islands followed from: the fact that victory in Europe was the higher of U.S. priorities; the different vulnerabilities and characteristics of the Japanese economy; and the differing personal views of some commanders. In U.S. post war debate the rival bombing philosophies (Congreve and EOU) can be generally described as the 8th/15th Air Force view and the 20th Air Force approach.

[15] The corresponding figure is 53% for one megaton weapons. The data here, expressed in terms of population residing within MLOP for a given weapon, is based on a Table in Armed Forces Journal International, May 1979, p. 26. Mean Lethal Overpressure (MLOP) is a "cookie cutter" measure. That is, MLOP describes the radius of the circle within which the number of survivors is assumed to be equal to the number of fatalities beyond the circle.

[16] Richard Hewlett and Oscar Anderson, The New World, 1939-45: A History of the United States Atomic Energy Commission, Volume I, Pennsylvania State University Press, University Park PA, 1962, p. 358.

[17] Fred C. Ikle, "Can Nuclear Deterrence Last Out the Century?" California Arms Control and Foreign Policy Seminar, Santa Monica CA, June 1974, p. 12.

[18] See K. N. Lewis and M. A. Lorell, "The Strategic Air Power Experience, 1914-1945: Forces, Plans, and War Objectives," (Rand Paper, forthcoming). Among other crucial lessons not learned in World War II were that strategic bombing then failed not only because of adverse cost exchange ratios but also because of (i) extensive slack in German production, (ii) dispersal and stockpiling tactics, and (iii) the relative "hardness" of tooling compared with industrial structures. Most important of all, even had the American bombing campaign destroyed its vertical objectives to necessary damage levels, the consequences of such action would be irrelevant unless other capabilities existed to take advantage of reduced German capability. To give just one example of this phenomenon, U.S. strategic interdiction operations against German lines of communication to Italy during Operation STRANGLE were on paper splendidly successful. But because entrenched German forces were not obliged to expend their consumables, destruction of logistic throughput bought little. Sympathetic though he was to the military aims and psychological corollaries of strategic bombing, Supreme Commander Eisenhower reassigned U.S. strategic air forces to what are today considered "tactical" objectives (in particular, communications nets) in support, first of TORCH, then of OVERLORD. Not until general air superiority over the Germans had been achieved and not until the allied invasion and the continued Soviet advance (including loss to ground forces of leading air targets like Ploesti) forced German industry to accept new inefficiencies and be reoriented to the point where strategic industrial bombing could show substantial payoffs were

bombing missions again undertaken to achieve strategic objectives.

[19] David Rosenberg, "American Atomic Strategy and the Hydrogen Bomb Decision," Journal of American History, June 1979, p. 64.

[20] Ibid., p. 66.

[21] Ibid., p. 67

[22] See K.N. Lewis, op. cit., Chapter II.

[23] USSBS, "The Effects of Atomic Bombs on Hiroshima and Nagasaki," Chairman's Office, 30 June 1946.

[24] Test data was so poor at the time that it is hard to draw hard and fast conclusions from available evidence. I am indebted to J. Carson Mark of the Los Alamos Scientific Laboratory for describing the uncertainties inherent in this analysis.

[25] Ted Greenwood, George Rathjens and Jack Ruina, "Nuclear Power and Weapons Proliferation," Adelphi Paper No. 130, London IISS, Winter 1976, p. 4.

[26] Richard Hewlett and Francis Duncan, Atomic Shield, 1947-52, History of the United States Atomic Energy Commission, Volume II, Pennsylvania State University Press, University Park PA, 1969, pp. 133-134.

[27] Ibid., p. 51.

[28] Ibid., p. 56. In retrospect, the ballistics of the bomb proved so poor that accurate aiming from the high altitude release point (mandated by aircraft free air escape constraints) could not be expected under most circumstances. Note that in the 1946 tests, the data collection effort was impaired by the inadvertent destruction of an instrumentation ship by the errant ABLE bomb.

[29] Cited in K.N. Lewis, op. cit. See Chapter III generally.

[30] See Jack Nunn, "U.S. Perceptions of the Soviet First Strike Threat, 1945-1961," unpublished Ph.D. dissertation, Department of Political Science, Massachusetts Institute of Technology, 1981, Chapter IV. U.S. A-bombing accuracy was far worse than had been previous conventional daylight bombing, which had improved to less than about 950 feet in World War II even under combat conditions. "Special Bombardment Study Mimeo," Memo to General Arnold from E.L. Bowles, and attachments, 28 August 1944, p. 4.

[31] JCS Document 1953/4, 23 October 1948. The probability of destroying soft targets with a 20 kiloton bomb with an accuracy of three miles is less than 10%, the exact value depending on HOB. Radar bombing tests using operational crews demonstrated CEPs of only 3.3 to 4.3 miles under idealized practice conditions.

[32] See "The National Defense Program--Unification and Strategy," Hearings before the Committee on Armed Services, U.S. House of Representatives, 81 Cong., 1 Sess., October, 1949, p. 170. An educated assessment of bomb effects would depend on the limited availability of technical data on nuclear weapons, which, through the end of the 1940s, were available only to a handful of cleared technical experts. Only in the Summer of 1950 did the first edition of the well-known handbook, "The Effects of Nuclear Weapons" appear. Even so, many effects remained poorly understood or even unknown. There is, for example, this striking example, concerning fallout: "For many of us our first exposure to the possibility of massive fallout came in 1951 with...the JANGLE series...Prior to that time the military doctrine as it was translated to us on the civilian side was that there would never be any point in exploding bombs close enough to the ground so as to get fallout; they wanted to maximize blast...So only airbursts were considered." Dr. Eisenbud, quoted in "Proceedings: Second Interdisciplinary Conference on Selected Effects of Nuclear War," DASA-2019-2 (NTIS), p. 40.

[33] P.M.S. Blackett, op. cit. "The mistake of Sir Arthur Harris and his followers is simply that they anticipated history in imputing to their blockbusters the destructive power of atomic bombs." Cited in Bernard Brodie, "More About Limited War," World Politics, 1957, p. 113.

[34] Jack Nunn, op. cit., Chapter III.

[35] JCS 1745/5, 15 August 1945, National Archives. This crucial bottleneck led some to worry that the Soviets might be able to knock out the deterrent by attacking the assembly teams; the JCS reportedly were concerned as the 1948 atom tests were being prepared that not all of the available U.S. teams be sent to the Pacific for the tests, and moreover, that attendees should not all travel in the same airplane. Kenneth Condit, "The History of the JCS," Volume II, 1947-1949, declassified pages, National Archives. Because weapons in peacetime normally were unassembled and not located at SAC bases in any case, the first and possibly most difficult operation SAC would have to undertake in a nuclear war would be the assembly and coordination of its far-flung men and materiel.

[36] Data on numbers of aircraft are from: Albert Wohlstetter, letter to Michael Howard, 6 November 1968; Ibid.; and JCS 1745/5, op. cit.; George Quester, Nuclear Diplomacy, Dunellen, New York, 1970, p. 5; Samuel Wells, Jr., "America and the MAD World," The Wilson Quarterly, Autumn 1977, p. 61; Samuel Huntington, op. cit.; and JCS 1745/5, dated 15 August 1945, National Archives. Note that an extended range B-29, the B-50, had entered service in 1948.

[37] Data on numbers of bombs are from Quester, Wells, and JCS 1745/5, op. cit.

[38] JIC 439/11, 23 October 1948, National Archives, and "Initial National Survivability Study," Stanford Research Institute, Technical Note SRD-EG34, Huntsville AL, October 1977.

[39] Taking into account lost Soviet population by all means (fallen birth rate, decreased life expectancy, etc.) the figure might more likely be on the order of 50 million. Oleg Hoeffding, "External Contributions to Soviet Postwar Reconstruction," unpublished working paper, Rand Corporation, Santa Monica CA, December 1975.

[40] Note P.M.S. Blackett, op. cit., p. 56 and p. 72; and Burton Klein, Germany's Economic Preparation for War, Harvard University Press, Cambridge MA, p. 235. In this respect, Blackett's argument that it would take "thousands" of atomic weapons to defeat the Soviet Union was plausible to a degree to which few commentators are willing to allow.

[41] Robert Kilmarx, A History of Soviet Air Power, Praeger, 1962, pp. 220-230. The USSR had obtained Rolls-Royce Spey jet engines and had impounded German engineers and plants relevant to aircraft production. The USSR had access to both German and American radar technology. Quester, op. cit., p. 41, notes that the USSR ultimately procured some 15,000 MiG-15 type interceptors. Kilmarx also reports that MiGs drove B-29s "from the (daytime) sky" over Korea. p. 227.

[42] See Albert Wohlstetter et al., "Selection and Use of Strategic Air Bases," Rand Report R-266, Santa Monica CA, April 1954, pp. 90 and 108.

[43] See also Curtis LeMay, America Is in Danger, Funk and Wagnalls, New York, 1968, pp. 83-84; and David Rosenberg, op. cit., p. 83. The debate continued in analytic circles without, however, formal resolution. A Weapons System Evaluation Group was created mainly to settle the Air Force-Navy dispute over the possible consequences of air attack. The results of its first report, dated 1950, can be considered relatively optimistic but WSEG/1 still concluded that 70-85% of bombers would reach their targets, that 50-75% would return, and that there would be severe basing problems. Moreover only between 1/2 - 2/3 of industrial installations attacked would be damaged beyond repair. Given the putative goal of a "knockout blow," this performance seemed inadequate.

The Joint Intelligence Committee estimated in 1949 that railways were the "Achilles heel" in the Soviet economy. See Anthony Brown, Dropshot, Dial Press, New York, 1978, p. 9. That is not a surprising conclusion. Rail has always been a superb target in the USSR. There are key bottlenecks: limited yard space, different rail gauge, etc. Moreover the Germans are said to have destroyed as much as 2/3 of the Soviet rail system in World War II: in the late 1940s, therefore, at least half of the work of destroying the Soviet rail system had already been done.

[44] "The Development of the Strategic Air Command, 1946-73," Historical Office, Hq SAC, Offutt AFB NB, September 1974, p. 151.

[45] Rosenberg, op. cit., p. 66.

[46] ibid.

[47] Samuel Wells, Jr., op. cit., p. 61.

[48] For yield data, see Melvin Carter and A.A. Moghissi, "Three Decades of Nuclear Testing," Health Physics, July 1977, p. 60.

[49] George Quester, Nuclear Diplomacy, op. cit., p. 6. The GREENHOUSE bombs yielded on the order of 50 Kilotons. (Note that the "750 bombs," the current force target, was just the predicted 200 bombs doubled and redoubled in number as a result of the SANDSTONE and CROSSROADS design improvements.)

[50] "Memo for the President," from General H.S. Vandenberg, dated 17 January 1952, p. 3. National Archives. Nuclear threat targets may or may not be limited in number, though these targets stress redundant, very high confidence coverage. Conventional military targets are limited in number, but difficulties in finding these targets, together with the special qualities of tactical situations, can also lead to huge weapons requirements. As to interdicting lines of communication, the number of targets of this type is effectively unbounded. There are perhaps four or five thousand bridges in the USSR, many canals, locks and inland waterway terminals, tens of thousands of "aim points" affiliated with rail and road transport, and so on.

[51] As yields increase, the destruction caused by the explosion's dynamic pressure phase increases at a faster than linear rate: this is most significant for U/I coverage. Thermal coverage also is disproportionately more effective at higher yields, because of increased fireball radiating endurance. But these and similar factors do not bear on the analysis here.

[52] See Herbert York, "The Debate over the Hydrogen Bomb," Scientific American, October 1975, pp. 111-12.

[53] See Robert Gilpin, American Scientists and Nuclear Weapons Policy, Princeton University Press, Princeton NJ, 1962, p. 91. Just five years earlier planners had specified 100 KT as the largest useful bomb yield (and only then such weapons would be required in limited quantity).

[54] Merton Peck and Frederic Scherer, The Weapons Acquisition Process, Harvard Business School, Cambridge MA, 1962, p. 229.

[55] I am indebted to J. Carson Mark of the Los Alamos Scientific Laboratories for his recollections on this point. See also Dr. Mark's essay and map in The Annual Review of Nuclear Science, 1976, New York.

[56] See testimony of Air Force Secretary James Douglas in Edmund Beard, Developing the ICBM, Columbia University Press, New York 1976, p. 140.

[57] See Robert Perry, "The Ballistic Missile Decisions," Rand Paper P-3686, Santa Monica CA, October 1967, p. 13. See also Phil J. Klass, Secret Sentries in Space, Random House, New York, 1971.

[58] Urban data derived from tables contained in Geoffrey Kemp, "Strategic Forces for the Medium Powers: Parts I, II, and III," Adelphi

Papers No. 106 and 107, London IISS, 1975.

[59] See H. S. Rowen, op. cit.

[60] The probability that individual bombers will survive the air battle is an exponential function of the number of aircraft taking part, the extent of exposure of bombers (usually measured by the time exposed or by the distance penetrated), and by a constant to describe in an aggregate way the nature of engagements. See Carl Builder, "The Penetration Integral and Tables: A Unifying Solution for Armament- and Encounter-Limited Air Battles," Rand Report R-1257, Santa Monica CA, June 1973. As a rule, saturating the defenses increases individual survival odds. In practice, however, appropriate offensive tactics such as defense suppression, careful route selection, countermeasures, and bomber self-defense can be effective. Accordingly, SAC has devoted prodigious efforts to increasing survival odds by investment in decoys, suppression of fighters and surface-to-air missiles, and so on.

[61] Data on budgets and SAC scale of effort taken from Kevin Lewis, op. cit. Chapter II.

[62] Fred C. Ikle, "Can Nuclear Deterrence Last Out the Century?" op. cit.

[63] William W. Kaufmann, The McNamara Strategy, Harper and Row, New York, 1967, p. 135.

[64] J. F. Dulles, speech before Council on Foreign Relations, New York City, 12 January 1954.

[65] W.W. Kaufmann, op. cit., pp. 50-52.

ACRONYMS

AEC	Atomic Energy Commission
CEP	Circular Error Probable, a measure of accuracy
EOU	Enemy Objectives Unit
FETO	Far Eastern Theater of Operations (World War II)
JSTPS	Joint Strategic Target Planning Staff
KT	Kilotons (thousands of tons of TNT)
MLOP	Mean Lethal Overpressure
MT	Megatons (millions of tons of TNT)
PAA	Primary Aircraft Authorized (formerly UE, for Unit Equipment)
psi	pounds per square inch, i.e. hardness to blast overpressure
SSPK	Single Shot Probability of Kill
USAAF	U.S. Army Air Forces
USSBS	U.S. Strategic Bombing Survey
WSEG	Weapon System Evaluation Group

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